CARBON EMISSIONS FROM CAR TRANSPORT UNDERMINE SUSTAINABILITY – A PRICKLY PROBLEM

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ABSTRACT

The need to reduce greenhouse gas emissions from human activity is now widely recognised. Internationally, a system of targets has been agreed. But everyday life seems to be carrying on much as before.

In the field of transport, Government rhetoric exhorts us to "travel smarter" but the complex set of reasons why we travel as we do does not seem to be being addressed. Government appears to lack a sound mechanism for identifying a set of policies that are necessary and sufficient for ensuring that emissions targets are met.

Focussing on car transport, various policies to reduce carbon emissions are possible, including:

- Land use measures to reduce the "need to travel" by co-location of dwellings, employment, retail, education etc in compact areas
- Measures to encourage modal shift by improvement of public transport and increasing the costs of car use
- Technological measures to reduce emissions by improving the efficiency of vehicles
- Measures to encourage the spread of newer and smaller-engined vehicles through the fleet
- Measures to reduce the proportion of driving in high-fuel-use conditions (sitting in queues, rapid acceleration, high speeds)

Arguably progress is being made separately in all these areas. What's missing is a realistic perspective on how these combine to give overall carbon savings. Which would allow political decisions that more needs to be done in some areas, or that conversely the price of a particular form of carbon saving – whether money cost or political cost - is too high.

This paper sketches out a systematic modelling framework for estimating national carbon emissions from car transport. Such a model needs to:

- estimate the total national impact of very localised measures being put in place in different sizes of settlement across the country
- strongly reflect the differences between the very urbanised and very rural locations, and everywhere in between
- reflect the underlying multiplicative structure (journeys x car share x length x emissions per veh-km) and generate appropriate sensitivities to policy action in each element
- incorporate significant feedback loops (eg. lower-fuel-use vehicles have lower running costs, so car journeys are cheaper, so other things being equal car mode share will rise.)

The process of putting together such a modelling framework would bring into sharp focus the limitations of present understanding and modelling tools, and should be setting the research agenda for the future.

Keywords: Emissions, modelling, national

1 THE GOVERNMENT FRAMEWORK

The need to reduce greenhouse gas emissions from human activity is now widely recognised. At the level of inter-governmental agreements, a significant response has been put in place. Some sectors of the economy are covered by the Emissions Trading Scheme (ETS), whereby a number of "carbon credits" – emissions permits - are allocated to firms operating major plants within the EU. Those firms whose emissions exceed their permit have to purchase credits to cover the difference; firms whose emissions are below target can sell their excess credits. The theory is that as demand for credits gradually exceeds supply, the price will rise, making emissions reduction more attractive, until an equilibrium price is reached. The ETS initially included only the energy (power generation) and industrial sectors of the economy, although there are plans to extend it to include emissions from aviation.

For non-ETS sectors of the economy, national-level targets have been agreed. The logic of the process is that within this overall target, the Irish government has to take decisions about sector-level targets for limiting carbon emissions. Then the Government Department that deals with each sector of the economy has to decide what measures to put in place in order to achieve these targets.

Such central government action might be direct measures, or include setting sub-targets for local authorities or delivery agencies, or campaigns to exhort individuals to reduce their own emissions by various means.

However, at the level of individual actions, there seems little sign of any major step-change in travel behaviour. Everyday life seems to be carrying on much as before. The outcome of these international agreements has yet to percolate down through the different layers of government to reach the ordinary citizen.

The whole top-down system is not yet connected up - targets have not yet led government agencies to put in place systems of incentives for rational individuals to change travel behaviour.

2 THE TRANSPORT ISSUE

The Environment Protection Agency (EPA) has published sector-level projections [1] of emissions to 2020. Figure 1 shows the published historic data that forms the basis of these projections. It can immediately be seen that emissions from transport are growing rapidly, while all other sectors are relatively static by comparison. If Ireland has an emissions problem, it is primarily a transport problem.

Transport as a sector is outside the ETS. The relevant national target is that the non-ETS sectors as a group should reduce their carbon emissions to 20% below the 2005 baseline, by 2020, with linear progress towards that point from 2013 onwards. The graph suggests that if that target were to be met by each sector individually, then emissions from transport would have to be more than cut in half in order to meet the national target.

The trend is based on pre-2008 data, and therefore does not allow for the effects of the recession. Whilst this may give Ireland a "breathing space" in which to decide what to do, it is clearly undesirable that a state of recession should continue. Once economic growth resumes, it seems likely that transport emissions will resume the observed upward trend, unless substantial policies are put in place to suppress this.

Figure 2 shows the contribution to the transport total from different modes and fuels [2]. (Energy use can be taken as a proxy for carbon emissions for this purpose). The dominant element is the private car, although road freight and aviation also form a substantial part. Public transport makes a negligible contribution to the total. Note that these figures are from 2006, when apparently fuel in the Republic was significantly cheaper than in the North, leading many drivers to cross the border to obtain cheaper fuel – so-called "fuel tourism". This is less of an issue at present, and it may disappear altogether if prices and exchange rates converge.

It is clear from this figure that while air travel may be an issue, making any significant inroads into transport emissions means tackling our use of cars and lorries.

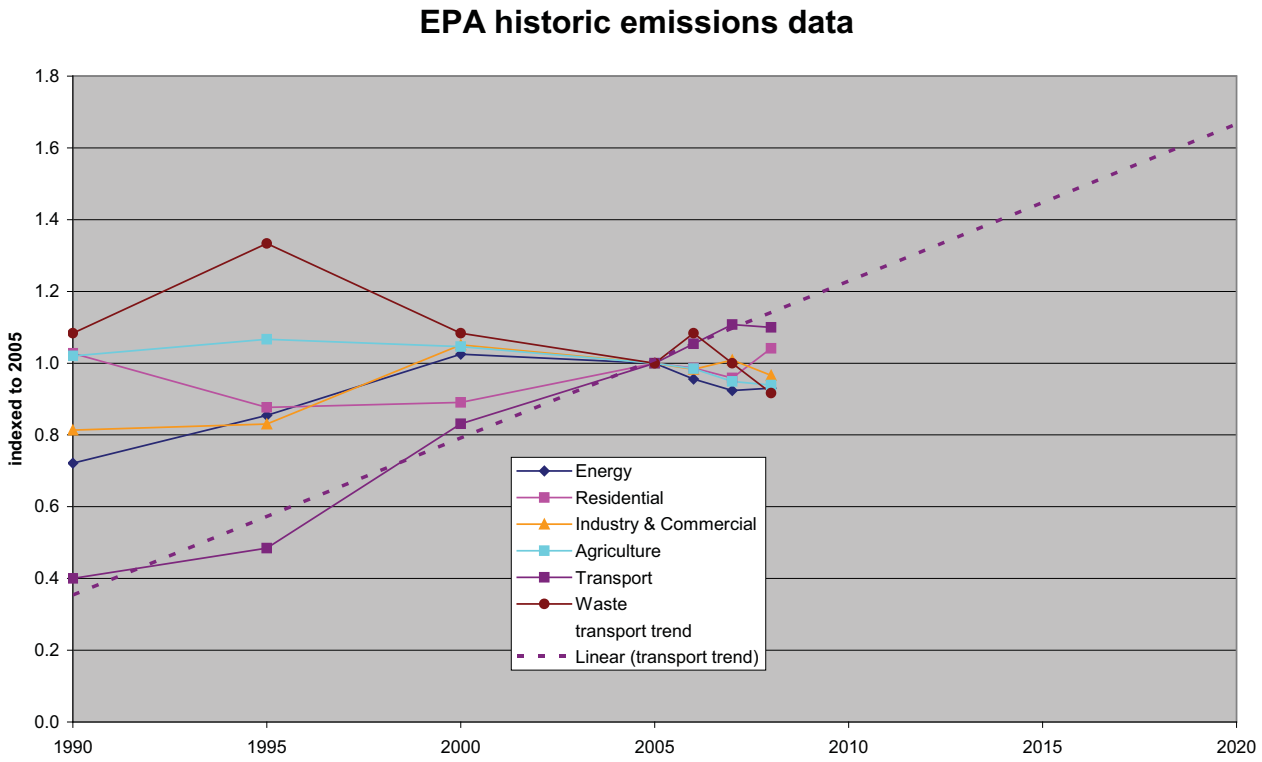

Figure 1: Emissions trends by sector (source: EPA)

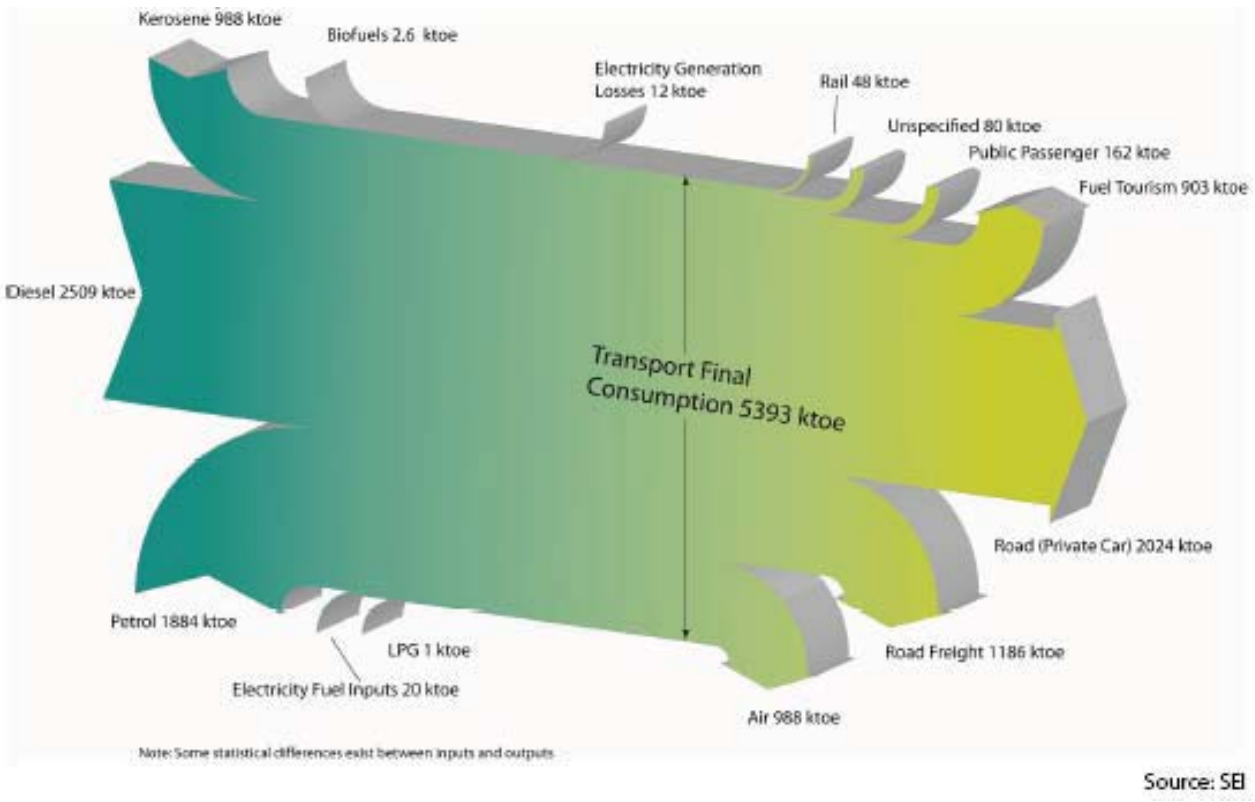

Figure 2: Summary of transport energy consumption (source: SEAI)

3 POLICY OPTIONS

The number of things that government could do which will have some impact on emissions from cars and lorries turns out to be quite large [3]. A sample of such policies is shown in Table 1 below – although not exhaustive, it illustrates the range of policy action available.

It is convenient to classify these policies into three main groups. The first group aim to influence mode choice, by reducing the cost or time or psychological barriers to using less-polluting modes, or by increasing the cost or time of owning or using cars. The second group aim to reduce the emissions resulting from our current travel patterns, by encouraging improvements to vehicle technology and the rapid adoption of these, and by addressing the manner in which we drive. The third group aim to change the context in which we take travel decisions, reducing the need for us to travel or the distance that we travel, by promoting alternatives to travelling at all, or promoting land use patterns which lead to shorter journeys.

Table 1: Summary of policy options

Encourage use of alternative modes by – Travel planning & information – Marketing – PT pricing & infrastructure – Walking & cycling infrastructure – Encouraging bicycle ownership Discourage car use by – Fuel taxes – Road pricing – Road capacity reductions – HOV lanes – Parking policy Reduce car ownership by – Regulating licence-holding – Supporting car clubs – Higher car taxes
Improve vehicle technology by – Support for development of low-emission vehicles Encourage uptake of such vehicles by – Regulating or taxing higher-emission vehicles – Changes to NCT rules – Information & advertising – Scrappage scheme – Low-emission zones "Eco-driving" – Speed enforcement – Improved traffic management
Change Land Use Patterns – Urban concentration – Urban design – Freight logistics Promote non-travel alternatives – Teleworking / teleconferencing – Internet shopping & deliveries

A case could be made for any of these. The challenge facing Ireland plc is what mix of such policies to adopt, so as to meet national targets at a minimum cost.

4 NEED FOR QUANTIFICATION

For costs there will be. Economists by tradition assume "rational man" – that if people are behaving in a particular way then they are getting something out of it. So that to bring about change, you have to make the undesirable behaviour less attractive and/or the alternatives more attractive. "Carrot" policies cost money that the government doesn't have, and "stick" policies can be very unpopular.

The issue known as the "tragedy of the commons" can apply at many levels, from nations seeking to gain economic advantage by not trying too hard to reduce their own emissions, to politicians not wanting to alienate supporters by backing unpopular policies.

We're all in this together – we have only one planet. If we don't act collectively to reduce emissions, all our grandchildren lose. But self-interest impels us at many levels not to do more than we absolutely have to in order to remove the environmental threat.

What we need is a realistic quantified perspective on how the impacts of different policy options would combine to give overall carbon savings. Which would allow informed evidence-based political decisions as to how much needs to be done in order to meet agreed targets.

Put another way, climate change from carbon emissions belongs to a category of "problems of success". Since man first discovered fire, he has been causing increased carbon emissions; it could be argued that the whole of our civilisation is built on exploiting this particular chemistry. So it is not that carbon emissions are an evil in themselves. It is simply a matter of how much is too much. Quantification is of the essence. What is needed is neither moral effort by individuals, nor campaigns to raise the consciousness of the uninformed, but rather identification by government of a set of policies that are necessary and sufficient to bring about the required reduction, and then the political will for implementation.

5 MODELLING FRAMEWORK

In other words, we need a National Transport Model that is designed to assess the combined impact of a wide range of policies to reduce carbon emissions from transport. Such a framework would draw on Ireland's considerable experience of transport modelling for other purposes – town-level traffic management studies, modelling for major inter-urban road schemes, multi-modal models of cities to inform city-wide public transport planning - but would face significant challenges.

Such a model may be thought of as having a number of components:

- A database of some sort that represents the totality of travel that is within the model scope
- A means of projecting this representation forward, taking account of both trends and feedback effects
- Mechanisms to represent the response of this travel to "policy levers"
- Emissions models that relate outcomes in terms of travel to emissions of atmospheric carbon (and any other pollutants that are within scope).

The level of detail of the representation (which includes dimensions of time, space, mode, personal characteristics / socio-economic variables, and trip purpose) will be determined by the requirements of all three of the subsequent steps. For example,

- a focus on emissions modelling may require the database to distinguish numbers of "cold starts" which would not normally be a feature of transport models.
- Sensitivity to policy levers (such as School Travel Plans) may require detail distinguishing school travel as a separate purpose, disaggregated by local authority, by distance to school, etc.
- If there is a trend towards ownership of larger-engined vehicles, then in order to include the effects of this adequately, substantial disaggregation by vehicle type may be needed.

6 SOME MODELLING CHALLENGES

Taking full account of all relevant trends, all policy levers that may be relevant and the data requirement for appropriate state-of-the-art emissions models could therefore result in a model that attempts an unmanageably-detailed representation of travel. A key aspect of any such model will therefore be the trade-off between the adequacy of the level of detail in the model and aspirations for the model to be simple to use and quick to run.

6.1 Computational feasibility

The extent of modelling all of Ireland does not of itself pose undue concerns - models of this size and greater are now quite widespread. However, computational effort can be considered as a product of geographical extent, geographical detail, market disaggregation and number of choice processes. Pushing the boundaries in too many dimensions at once very quickly gets to a point where the model is cumbersome and less useful than intended.

For example, the existing NTA model covers around one-third of the population of the State, and takes around 20 hours to run. A national model at similar level of detail might have three times as many zones. Such a model might take around nine times as long to run, since many of the operations within a conventional transport model are matrix-based and therefore their execution time goes up with the square of the number of zones.

One early challenge is to consider the hardware and software platforms on which such a model might be run. A model that runs on a "high street" PC may require substantial compromises in terms of detail. Investment in high-end industrial computing power may or may not be more cost-effective than development of algorithms to carry out particular calculations as efficiently as possible with limited processing power. Transport modelling methods are increasingly reflecting opportunities for large-scale parallelized models that modern computing technologies support, and this may be an appropriate approach.

6.2 Data

The high-quality Census data and related POWCAR journey to work data that was collected in 2006 and is due for update in 2011 provides an important basis for establishing travel demand for some purposes. In the Dublin area the 2006 Census was complemented by a Household Travel Survey and a Travel to

Education Survey that provided the basis for developing an all-day picture of travel demand in the Dublin area. This approach could feasibly be extended across Ireland to serve the NTM in describing personal travel.

Similarly, the existing NRA highway model and digital network data provide the basis for a national highway network.

Establishing public transport network descriptions is less straightforward, except that the information for key areas, notably Dublin and Cork, already exists for the present day case. Extending and updating this information at a national scale is thus viable.

Information on freight, aviation, and shipping may be largely insufficient and of poor quality. As these modes are responsible for significant levels of emissions, there is a requirement to improve the provision of data.

Aggregate statistics on sale of fuel may provide a useful top-down control total for bottom-up estimates of the amount of fuel burned and thus carbon emitted; similar issues may arise in terms of other items of data.

The factor having the largest single impact on emissions may well turn out to be the rate at which improvements to vehicle technology can be brought on-stream. The rate of uptake of available higher-technology vehicles (and the impact of measures such as scrappage schemes which seek to accelerate such uptake) can be modelled using various techniques. But there is likely to be no sound evidence base for assumptions on the likely (exogeneous) rate of such technological development, and the best available data may be some form of a consensus of informed stakeholders.

6.3 Cross-Border issues

The natural geographical scope seems to be an all-island model, but there are several issues around this, including:

- Issues of data consistency
- The likely inability of synthetic or extrapolated models to replicate patterns of movement across the border
- The sensitivity of cross-border shopping and other trips to relative prices and taxes within the two administrations
- The allocation for accounting purposes of emissions from fuel which is purchased in one administrative area and used in the other.

Whether or not an all-island model turns out to be politically feasible, it will be important to be clear on how emissions connected with international journeys are to be dealt with – defining precisely the scope of the modelled journeys and corresponding emissions.

6.4 Modelling Methodologies

Existing national transport models in other countries tend to be based on a disaggregate choice modelling approach to demand, coupled with multi-modal network models that calculate travel costs and network loadings, iterated to a "user equilibrium" in which no traveller can increase their utility by choosing a different route, mode or destination. This provides a general 'default methodology'. A typical multi-modal choice structure might be as shown in figure 3. However, extending this to all relevant lifestyle choices (including age and type of vehicle to own) and interactions between trips (trip chaining, cold starts) may lead to significant problems in achieving convergence to equilibrium. Arguably, much of the time our lives are not in equilibrium – transaction costs mean that we hang onto the house and car that were appropriate a few years ago.

Other styles of modelling, notably those involving a greater degree of simulation (agent-based, and the like), provide means to address issues ignored or inaccessible to more established approaches. Alternatively, of particular interest may be various "meta-modelling" approaches, where a series of detailed models feed information on policy sensitivities up to an overarching less-detailed higher-level model.

At the very least, it may be necessary to take full account of those very short car journeys which in most models would be intra-zonal and thus ignored; these may be the trips where there is most scope for switching to more sustainable modes of travel.

6.5 Changing Behaviour

One methodological challenge lies in the assessment of measures which aim to change behaviour in favour of more sustainable modes of travel. Any forecast involves some form of extrapolation from past to future; if such

"hearts and minds" measures were successful in causing a genuine "paradigm shift", the outcome would almost by definition be unforecastable. Thus whatever the rhetoric, for forecasting purposes it will be necessary to construct a framework for extrapolating impacts from existing case studies (in Ireland where possible, but otherwise from other countries).

7 CONCLUSION

If such a model is to be developed in time to influence the achievement of Ireland's 2020 emission target, it will need to be assembled on a modular basis in an initial version that represents the current state of knowledge using existing off-the-shelf tools. And then refined over time, as our understanding improves and better data sources become available. The model then becomes a sort of repository of our collective knowledge; correcting its most obvious shortcomings may (perhaps should) determine the agenda for applied transport research over the next few years.

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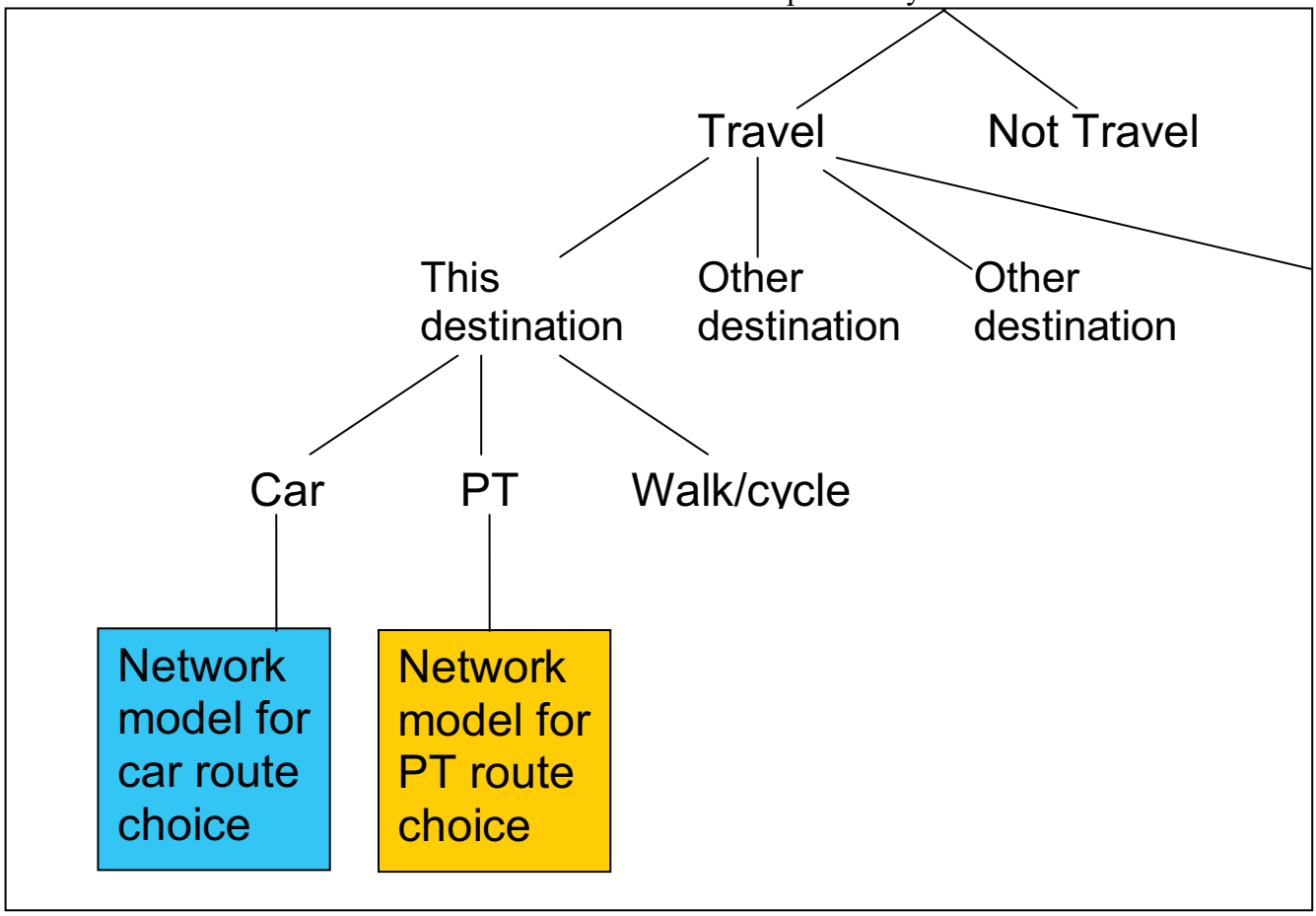
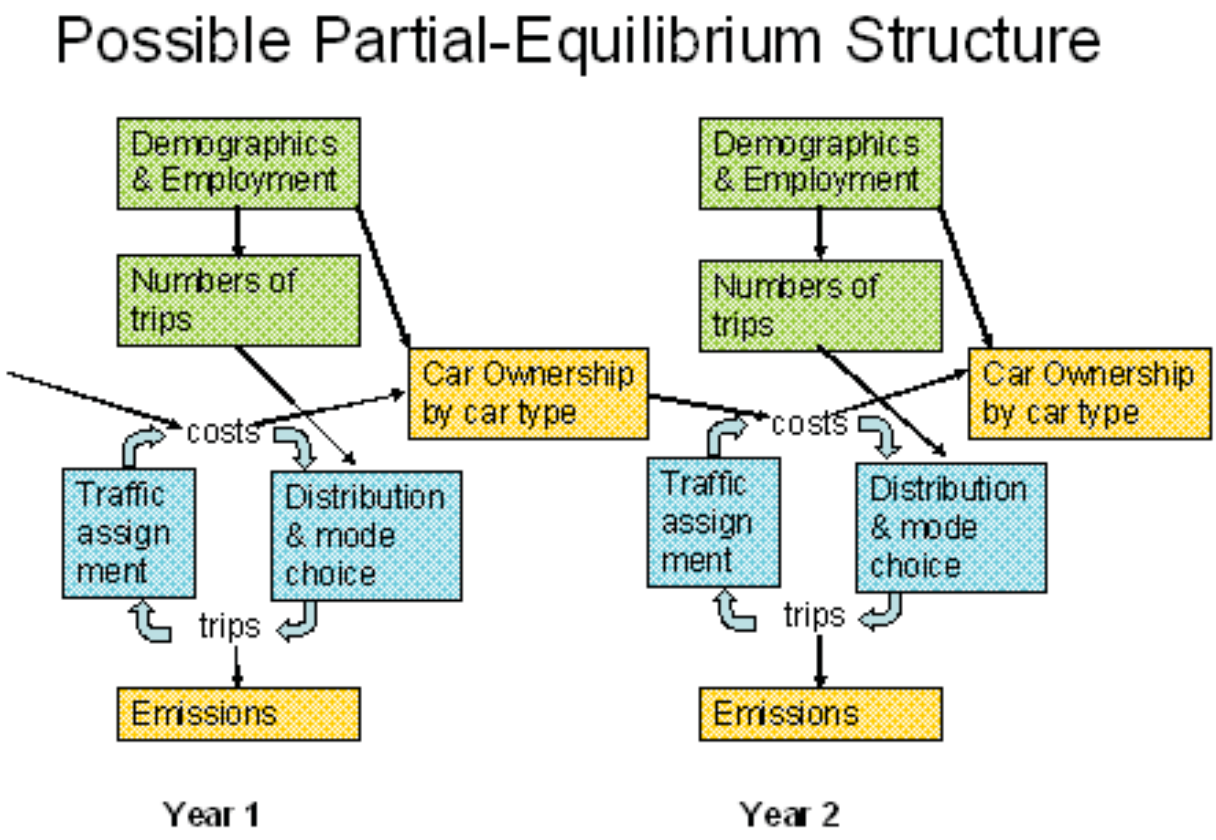


Figure 3: Typical multi-modal structure for city-level modelling



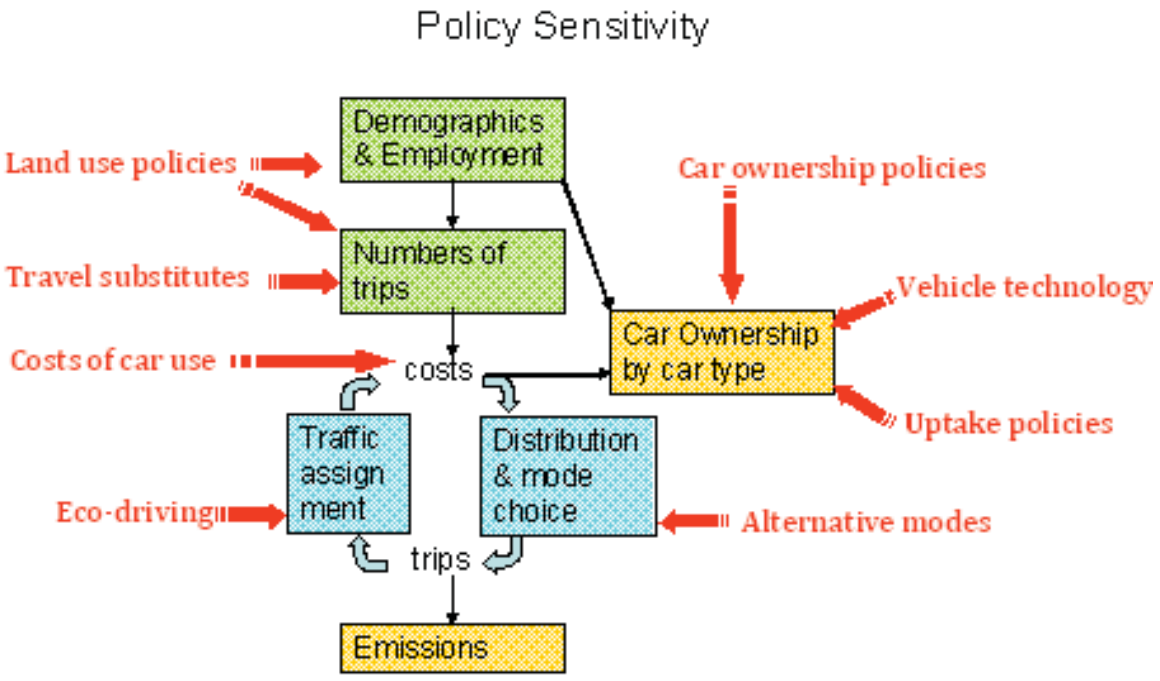


Figure 4: Possible Outline Structure

WALKABILITY MEANS WHAT, TO WHOM? DIFFICULTIES AND CHALLENGES IN DEFINING WALKABILITY

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ABSTRACT

There has been considerable growth in public health research investigating the influence of the built environment on physical activity. Simultaneously, transport and planning professionals have been promoting a change from inactive to active transport modes to reduce traffic congestion and air pollution. A core concept in both areas of research is 'walkability'. Walkable areas are varied and professional opinion on the level of walkability of an area can be contradictory. This study used a researcher-developed questionnaire to assess the environmental factors that influence walking behaviour. Professionals working within the areas of planning, architecture, politics, advocacy, public health and engineering were invited to complete the online questionnaire. All professions agreed that the presence of local quality functional walking routes, the availability of numerous destinations within walking distance and the perception of safety were all key factors that influence the walkability of an area. However, professions disagreed on the role of aesthetic factors; visual interest along a route was given a higher priority by some professions than others. It was concluded that different professions have different understandings of the concept of walkability, and future research should employ qualitative methodologies to investigate these differences further.

Keywords: Walking, Walkability, Smarter travel, Urban environment

1 INTRODUCTION

In recent years there has been considerable growth in public health research investigating the influence of the built environment on physical activity [1-5]. Simultaneously, transport and planning professionals have been promoting a modal change to active transport modes to reduce traffic congestion and air pollution [6-8]. A core factor in both areas of research is the concept of the 'walkability 'of an area.

International literature suggests that walkable areas are favourable to good health and sustainable transport [2-9]. The factors used to identify or define an area as walkable are varied and often contradictory. This is due, in part, to the different opinions held by those responsible for designing and building theses 'walkable' areas [10-14].

2 WALKABILITY

Words commonly used to describe how conducive an area is to walking are 'walkable' or it's 'walkability'. An area which is pedestrian friendly can be deemed to be more walkable than one which is not. Walkability is a multidisciplinary concept which means different things to many different people depending on the context in which it is being investigated. Lo [14] notes that considering the question of 'what is walkability?' it seems that who you are asking is as important as the question.

2.1 Walkability stakeholders

Previous research on walkability and the determinants of walking behaviour has included the views of architects, landscape architects, urban planners, urban designers, transport planners, academics, government decision makers, social ecologists, public health professionals and user advocacy groups [4,12,15].

This multidisciplinary expert opinion was sought in order to develop an understanding of the built environment factors which influence walking. Allender [15] found that public health research relating to walking determinants was reflected in the "accepted wisdom" of those involved in the design process. Lee [16], a

spatial planner, found that research in the urban/ transportation fields was "complementary" to the public health research and he recommended that "future multidisciplinary research is likely to promise a better understanding of both the behavioural and environmental aspects of physical activity and physically active travel"(pp167). However, no research was identified that compared how the concept of walkability differed between professionals from various fields of expertise. These professional groups include planners, architects and designers, public health and advocacy professionals, public representatives and engineers. The purpose of this research was to explore the multidisciplinary nature of 'walkability' that exists among these groups and to examine any common ground or contradictory practices that might exist.

Planners

In relation to 'walkability' planners can be divided into two categories, spatial planners and transport planners. Spatial planners are concerned with land uses, they ensure that new developments have access to services, they plan and enforce sustainable development, urban renewal and the diversity of destinations. Spatial planning has two primary functions, forward planning and development control. Forward planners plan for future growth and decide the variety of land uses. Development control planners manage physical development by processing planning applications and enforcing planning law [17,18].

Transport planners provide for the movement of people including the design, routing and provision of roads, public transport, footpaths and bicycle lanes. They measure and project the demand for transport modes and design systems to suit and inform decisions on transportation investment [19]. Their role is fundamental in generating trips. The built environment factors which planners and transport planners consider as tools to encouraging walking are densities, land use mix and the formation of the street network [2,20]. Transport for London has a walkability index [11] which treats walkability solely as a framework for walking. It outlines factors and instructions for the provision of pedestrian infrastructure in a format similar to motorised transport design manuals.

Architects and Designers

Professionals involved in the design of streetscapes are primarily urban designers, architects and landscape architects. Urban designers have been advocating walkable communities for decades [21]. Lynch [22], Gehl [23] and Cullen [24] suggest that successful, comfortable and safe places encourage people to walk and explore on foot. Similar to spatial and transport planners, urban designers emphasise nearby destinations with quality routes to access them as factors to encourage walking trips. However, they go a step further than the planers and highlight the need for routes to offer comfort and visual delight in order to make the trip enjoyable [10,24,25]. Architects and landscape architects design for comfort and visual delight.

Public Health and Advocacy Professionals

Advocates can be divided into two groups, those whose main purpose is to promote health through walking, and those who want to promote walking for its own sake as a pleasurable activity.

Studies from public health researchers include those to determine the hierarchy of factors that influence walking [4], differentiate between perceptions, and actual measures of neighbourhoods [26], and those that determine how different cohorts of society are influenced [2,27].

Walking advocate Les Burden defines Walkability as "the extent to which the built environment is friendly to the presence of people walking, living, shopping, visiting, enjoying or spending time in an area" [28]. Community based walkability advocates produce a more holistic definition of walkability as they are not confined to a particular research areas or limitations determined by their professional training.

Public Representatives

In Ireland, local government planning, engineering and transportation planning departments oversee urban and rural development, the design of which is sometimes undertaken by private design consultancies. Local governments are advised and informed by national policies and strategies developed by government departments and agencies such as the Department of Transport; the Department of the Environment, Heritage and Local

Government; the Department of Community, Rural and Gaeltacht affairs; and the National Transportation Authority. The policies, plans and budgetary spending proposals of these government agencies or departments are approved by elected national or local government officials. In this role they have the potential to influence the financial resources allocated to walkable environments.

Engineers

Whilst the transport planners decide the routes, engineers are tasked with designing, building and maintaining of the pedestrian infrastructure and road crossings along the route. In the absence of street design standards, the design of such infrastructure is guided by standards such as the Design Manual for Roads and Bridges (DMRB) written for large highways. In the DMRB priority is given to motorised vehicles and infrastructure for pedestrians is often only considered "where the perceived level of usage by pedestrians justifies their inclusion" [29] (pp. 4/1).

2.2 Summary

In summary, walkability is a complex issue. Many descriptions or definitions are used by individuals, professionals or groups to articulate what they mean by the concept of walkability. Evidence suggests that walkability definitions to date are a combination of the hierarchy of factors relevant to the person defining, and reflecting the needs of their target group. It was also noted that some factors can be more or less influential on walking behaviours depending on climate and cultural factors. The purpose of this research was to explore the multidisciplinary nature of 'walkability' that exists among these professional groups.

3 METHODOLOGY

3.1 Questionnaire development

The international research team consisted of individuals qualified in the areas of public health, exercise science, transport planning, sociology and political science. A review of literature on walkability and on the built environment determinates of walking was undertaken by the research team, and over a 9-month period a list of factors known to influence the 'walkability' of an area was generated. An additional number of exploratory items were also included in the final list.

Factors

This list of environmental (physical and social) factors (47 items) was converted into a web-based questionnaire. The questionnaire used a 5-point Likert scale from 1 – very bad for walkability to 5 – very good for walkability for items like 'Cul-de-sacs' or 'Poor air quality/ presence of air pollution'. Negatively worded factors were reverse coded to allow for comparative analysis on a continuous scale.

Study hypotheses

Respondents were asked 'to what extent do you agree with the following statement', each statement reflected a study hypothesis. Statement 1: 'Human health is affected by the way we plan and design our communities and transport systems and Statement 2: Carbon emissions are effected by the way we plan and design our communities and transport systems'. Responses were measured on a 5-point Likert scale from 1 – Strongly Disagree to 5 – Strongly Agree.

3.2 Validity testing

Nine researchers evaluated the validity of the questionnaire, by completing it and then discussing the validity of each question and its corresponding responses. These discussions were facilitated by a single researcher (Leyden) and took place in face-to-face meetings or on the telephone. All of the validity testers, worked in relevant areas (universities or government), had PhDs and were based in Ireland (n=6), the United States (n=2), or Spain (but from France) (n=1). Most had considerable experience with questionnaire design and analysis and most had conducted research related to walkability or the built environment. All input was discussed and recorded and used to improve the design, validity and quality of the instrument used in this study.

3.3 Reliability testing

A 7-day test - retest reliability analysis was carried out on the questionnaire with exercise science, transportation planning and spatial planning students (N=66, 58% male, average age 21.2yrs $\pm$ 1.28). Level of agreement at time one in comparison to time two was assessed using Statistical Package for Social Sciences (SPSS) statistics software, version 17.0. Level of agreement was acceptable ranging from 40%

to 74% for built environment factors and 52% to 84% for demographical factors.

3.4 Recruitment and distribution

The stakeholders identified for this study were professionals and academics from the areas outlined in section 2.1. The questionnaire was hosted on www.surveymonkey.com and the survey link was distributed by email.

Lists of potential research participants were generated from a number of strategies. The entire population of elected public representatives for urban regions of the Greater Dublin Area were targeted. The delegates attending relevant conferences hosted by the Department of Transport, the Irish Sports Council, the Health Service Executive and the Engineers Ireland were selected. A systematic identification of relevant third level courses was undertaken to identify academics. Individuals from the identified stakeholder fields were contacted from listings from the golden pages telephone directory and from an internet search using the google search engine.

Once this list of potential participants was generated, two recruitment methods were employed. Firstly, emails with the survey web link were sent directly to individuals and secondly emails were sent to companies and institutions for wider distribution.

3.5 Ethics

Ethical approval for this study was obtained from the Dublin City University Research Ethics Committee.

3.6 Data Analysis

All data were stored, cleaned and analysed using Statistical Package for Social Sciences (SPSS) version 17. Means, standard deviations and proportions were used to describe the data where appropriate. For each professional group, variations in data on level of agreement with study hypotheses and on factors influencing walkability were examined using a one-way independent ANOVA, with Games-Howell post hoc tests. Only factors found to be significantly different between groups are reported in the results.

4 RESULTS AND FINDINGS

4.1 Response rate

A response rate of 28% (N=173 out of 609) was obtained from the individual emails recruitment method. An additional 46 surveys were completed by the second recruitment method, giving a total of 216 responses. Independent samples distribution analysis was carried out to assess differences in the age, gender, profession or level of streetscape design experience between respondents recruited from both survey links. No significant differences were found between the samples on any of these variables, and so both datasets were combined for full analysis.

Area of work

Respondent numbers, grouped by area of work are shown on Table 1. Geographers were grouped with spatial planners and environmental policy professionals were grouped with public health and advocacy professionals.

Table 1: Survey response distribution by professional group

Professional Group	Number	%
Spatial Planning (SP)	33	15
Transport Planning (TP)	39	18
Architecture & Design (AD)	36	16
Public Health & Advocacy (PHA)	28	13
Public Representative (PR)	38	17
Engineering (E)	42	19
Total	216	100

4.2 Agreement with hypothesis

The mean and standard deviation score for agreement with the study hypotheses were 4.66 $\pm$ 0.6 for human health, and 4.64 $\pm$ 0.6 for carbon emissions. The group statistics are presented on Table 2.

Table 2: Agreement with hypothesis statements

Profession Group	Human Health (p<0.05)	Carbon Emissions (p<0.05)
Spatial Planning (SP)	4.64 (.5)	4.70 (.5)
Transport Planning (TP)	4.62 (.7)	4.64 (.5)
Architecture & Design (A&D)	4.83 (.6) [1]	4.78 (6)
Public Health & Advocacy (PHA)	4.89 (.3) [2]	4.71 (.5)
Public Representative (PR)	4.68 (.7)	4.68 (.5)
Engineering (E)	4.38 (.8) [1,2]	4.38 (.8)

Note: Values are means (standard deviations). ANOVA p<0.05. Games-Howell post hoc, [1] E vs A&D, p<0.05, [2] E vs PH&A, p<0.01.

A significant difference was recorded between professional groups on their level of agreement with the human health hypothesis ($F(df)=3.04(5)$, $p<0.011$), and post-hoc tests revealed that this difference was due to the mean score of engineer group being significantly lower than either public health and advocacy, or architecture and design groups (Table 2). A borderline between group difference was found on the carbon emissions hypothesis ($F(df)=2.3$, $p<0.046$), however this difference was not substantiated in the post hoc analyses. Factors influencing walkability

The top five environmental factors that influence the walkability of an area according to the respondents were i) well maintained footpaths, ii) services (e.g. shops, schools) within walking distance of peoples homes, iii) well designed pedestrian crossings, iv) crime rate, and v) access to parks or other green spaces (Figure 1). The factors with the least influence were building height, residential density and pedestrian bridges.

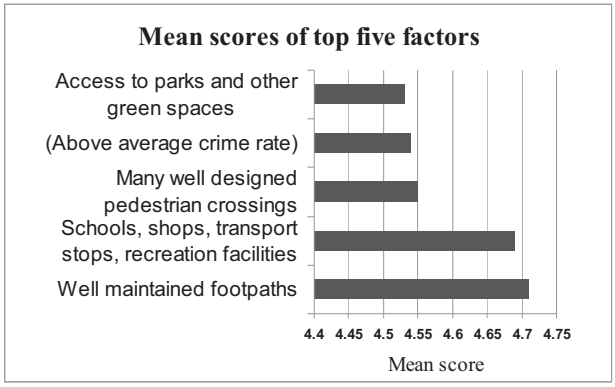

Figure 1: Mean scores of top five most influential factors

A significant difference was recorded between professional groups on the contribution of seventeen of the forty seven factors to the walkability of an area. These factors are shown on Table 3. Spatial planners rated destinations, pedestrian crossings and well maintained footpaths as their top three influential factors. They rated attractive gardens, people begging and footpath congestion significantly lower in their influence on walkability than architects and designers, engineers and public representatives respectively.

Transport planners rated well maintained footpaths, destinations and cul-de-sacs as their top three influential factors. They rated seven factors significantly lower than architects and designers; these included overlooked routes, unique characteristics of the area, attractive gardens and mixed age profile of people living in the area. They rated four factors lower than public health and advocacy professionals; these included the presence of benches and mixed age profile of people living in the area. They rated the influence of pedestrian bridges significantly lower than either public representatives or engineers.

Architects and designers rated walkability factors higher, on average, than all other professional groups. Specifically, they rated destinations, well maintained footpaths and green spaces as their top three most influential factors. On only one factor, the presence of pedestrian bridges over roads, did they rate its influence significantly lower than any other professional groups (these were public representatives, public health and advocacy professionals).

Public health and advocacy professionals and public representatives rated well maintained footpaths and destinations as their top two, while public health placed proximity to green spaces as number three and crime rate was the third influential factor for public representatives. Both groups rated the overlapping functions of an area and if walking routes were overlooked significantly lower than architects and designers

Engineers rated walkability factors lower, on average, than all other professional groups. They ranked the crime rate of an area ahead of well maintained footpaths and pedestrian crossings in their top three factors. They rated eight factors significantly lower than architects and designers, and four significantly lower than spatial planners. These factors included proximity to services, proximity to friends and family homes, availability of public spaces for people to gather and residential density.

5 DISCUSSION

5.1 Findings on Study Hypotheses

This study represents the views of numerous stakeholders from different professional groups involved in designing and building walking environments or promoting walking behaviour. This group agreed that the way we plan and design our communities and transport systems affects human health. The level of endorsement was significantly lower among engineers than other professionals, indicating a potential lower

Table 3: Mean scores and standard deviations for factors by area of work

	Professional Groups						
Walkability Factors	**SP**	**TP**	**AD**	**PHA**	**PR**	**E**	**Games Howell Post Hoc**
Schools, shops, transport stops, recreation facilities and other services within walking distance from people's homes	4.85 (.4)	4.59 (.8)	4.92 (.3)	4.75 (.4)	4.68 (.6)	4.45 (.6)	E<AD[2] E<SP[1]
Friends/ family's homes within walking distance	4.52 (.5)	4.32 (.6)	4.63 (.5)	4.46 (.70	4.35 (.6)	4.24 (.5)	E<AD[1]
Public spaces where people can gather	4.18 (.5)	4.00 (.6)	4.31 (.8)	3.88 (.8)	4.11 (.7)	3.59 (.8)	E<AD, SP[2]
Mixed land use (variety of shops, residences, amenities and other uses)	4.31 (.6)	4.14 (.7)	4.33 (.5)	4.23 (.7)	4.07 (.6)	3.95 (.5)	E<AD[2]
(Low residential density)	3.38 (.8)	3.27 (1.0)	3.59 (.8)	3.12 (.9)	3.03 (.8)	2.80 (.9)	E<AD[2] E<SP[1]
Over lapping day and night functions in an area	4.34 (.5)	4.11 (.7)	4.67 (.5)	4.04 (.6)	4.18 (.5)	4.20 (.6)	E, PHA, PR, TP< AD[2]
Route overlooked by occupied buildings, shops and residences	4.42 (.6)	4.16 (.7)	4.64 (.6)	3.70 (.9)	3.84 (1.0)	3.66 (.9)	E<SP[2] E, PHA, PR <AD[2] TP < AD[1] PHA < SP[2]
(High walls surrounding properties)	4.09 (.7)	3.94 (.7)	4.42 (.7)	3.89 (.8)	4.03 (.7)	3.83 (.7)	TP<AD[1] E<AD[2]
Unique areas with personality and character	4.24 (.7)	3.92 (.6)	4.51 (.6)	4.48 (.6)	4.19 (.7)	4.27 (.5)	TP<AD[2] TP<PHA[1]
(Cul de Sac's)	4.25 (1.0)	4.54 (.7)	4.50 (.6)	3.96 (1.0)	3.89 (.9)	4.17 (.9)	PR<AD, TP[1]
Attractive gardens & trees along route	4.09 (.6)	3.95 (.6)	4.50 (.5)	4.25 (.6)	4.38 (.6)	4.17 (.7)	SP<AD[1] TP<PR[1] TP<AD[2]
Benches to stop and rest	4.24 (.7)	3.92 (.5)	4.39 (.6)	4.33 (.5)	4.25 (.6)	4.15 (.6)	TP<AD, PHA[1]
(People begging)	3.72 (.7)	4.19 (.7)	3.72 (.8)	4.00 (.8)	4.17 (.8)	4.20 (.7)	SP<E[1]
(Congestion on footpaths)	3.67 (.8)	3.89 (.6)	3.81 (.7)	4.08 (.6)	4.29 (.7)	4.00 (.8)	SP<PR[1]
(Large flat carparks)	3.91 (.7)	3.74 (.8)	4.19 (.8)	3.41 (.8)	3.91 (.8)	3.90 (.7)	PHA < AD[2]
Mixed age profile of people living in the area	3.74 (.9)	3.47 (.6)	4.03 (.8)	4.08 (.6)	3.61 (.6)	3.70 (.7)	TP<AD[1] TP<PHA[2]
Pedestrian bridges over roads	3.52 (1.1)	2.94 (1.1)	3.25 (1.1)	4.04 (.8)	4.04 (.9)	3.73 (.9)	TP<PHA, PR[2] TP<E[1] AD<PHA, PR[1]

Note: Values are means (standard deviations). [1]$p<0.05$, [2]$p<0.01$. Due to reverse coding range of scale 3-5, where 3 = no influence and 5 = influential. Reverse coded items are in parenthesis

priority of this area. No group differences were recorded on the level of agreement on how the way we design our communities and transport systems affects carbon emissions. All groups strongly agreed with this hypothesis.

5.2 Findings on walkability factors

Respondents indicated that a common understanding exists on the importance of well maintained footpaths which is consistent with the literature across disciplines [1-5,10-12,14,20-28]. Analysis of data revealed that beyond the functional path professional groups think differently about walkability. Strategic planners and architects and designers rate the proximity to services/destinations top of their list of influential factors consistent with their professional descriptions [10,18].

Architects and designers rate significantly higher on more factors than any other profession and gave the highest mean score to the majority of factors suggesting a greater understanding of walkability consistent with statements by Forsyth and Southworth (2008) [21].

Engineers display a functional perspective on walkability which lends support to Lo (2009) [14] who highlighted the tendency of engineers and traffic planners to treat pedestrians like motorised vehicles with little consideration for factors not relating to the functional route. Engineers generally rate walkability factors lower than other professions. This would suggest that engineers are less aware of the impact that the built environment can have on an individual's decision to walk. Consideration of the fact that engineers and public representatives rated overlapping day and night functions of an area, overlooked routes and the influence of high walls significantly lower than architects and designers and rated crime in their top three factors influencing walkability would imply a lack of understanding of the functional purpose of these factors on the safety of an area.

Traffic planners were high on connectivity factors (the influence of cul-de-sacs) and proximity to destinations, but significantly lower than architects and designers on aesthetics (unique areas, gardens and trees) which supports the methods recommended by Frank and colleagues (2008) [2] and Cervero and Kockelman (1997) [22] to measure walkability.

This study found that residential density rated second lowest on influence on walkability out of forty seven factors. This is contradictory to many studies [1-5,20,26,27]. These studies suggest that higher densities result in closer proximities to services. The high ranking of proximity to destinations and the low ranking of residential density would suggest that density itself is not an issue provided services are nearby.

The results also highlighted potential differences between the ideal theoretical perspectives and the actualities that exist. Public representatives and public health and advocacy professionals rated the influence of pedestrian bridges significantly higher than transport planners and architects and designers. There is an accepted understanding among designers that pedestrian bridges do not always function as intended, as outlined in Räsänen and colleagues (2007) [30], this research suggests that this may not be apparent to public representatives and public health and advocacy professionals. Similarly, public representatives rated the influence of cul-de-sacs significantly lower than transport planners and designers; this highlights a potential conflict of understanding of the influence of cul-de-sacs/ closed off estates, which have been popular in recent years, on the walkability of the area.

Public health and advocacy professionals rate green spaces as the third most influential factor on the walkability of the area. The also rated unique areas with personality and character, benches to stop and rest and a mixed age profile recognising the recreational and social aspects to walkability.

6 CONCLUSIONS

The findings suggest that all professions agree that the presence of quality functional routes, destinations within walking distance and perceptions of safety on the walkability of an area. However the importance of aesthetic factors, the visual interest along a route, the presence of cul-de-sacs, the availability of benches, and having people of mixed age profile in an area received a higher priority for some professions than others. Ultimately, this difference in opinion could affect what is included in an area or what is excluded. Our challenge is how to communicate the key factors influencing walkability to the key

decision makers who design and build our environments.

7 ACKNOWLEDGEMENTS

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CYCLING PROMOTION IN A UNIVERSITY CONTEXT EXPERIENCES AND OPPORTUNITIES

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ABSTRACT

Cycling as a sustainable mode of transport has significantly gained momentum in Ireland within the recent past, not least through the Government's Smarter Travel initiative and the publication of its first National Cycling Policy Framework. The DublinBikes rental scheme has proven to be far more popular than anticipated, and there are increasing numbers of cyclists on the roads of Irish cities.

Large employers and educational institutions, especially universities that combine both functions, can play a major role in promoting bicycles for everyday use at local level. University College Cork has committed itself to persistently promoting cycling among its staff and students, totalling a college population of c. 19,000. This paper shall show from a practical perspective what can be done to promote cycling in a university context, beyond the obvious such as the provision of high quality bicycle racks and the adoption of the Government's Employer Bicycle Scheme. In this regard the paper will for instance present a small scale bicycle rental scheme, which UCC presently is preparing for its campus.
But as the Universities' immediate influence is limited to the campus boundaries, it will further be shown what needs to be done in terms of safe and comfortable access routes for cyclists to campus, in particular by the local authorities. Cycle lanes and tracks will come to people's minds first. However, there is much more that can and needs to be done in addition to red paint on the tarmac of existing urban main roads. Here, a closer look will be taken at the aspect of a more sustainable layout of the (sub)urban built environment, where the Government and the local authorities are in charge in terms of planning guidelines and practices, emphasising on "permeability" of the urban fabric for non motorised modes of transport.

A significant long term modal shift to non motorised modes of transport, apart from enhanced public transport, will be critical for meeting long term reduction targets for carbon emissions, as it can be assumed that an increased efficiency of car engines alone will not suffice.

Keywords: Cycling, University, Workplace, Road Infrastructure, Urban Planning, Sustainable Travel

1 INTRODUCTION

In small- and medium-sized towns and cities, where many everyday journeys only cover a few kilometres, cycling can be an ideal means of transport. For distances between one and five kilometres, cycling can often be quicker than driving, given inner city road networks that usually are clogged during the morning and evening rush hours.
University cities happen to be an ideal case for cycling. A mostly young student population can avail of a cost-effective means to fulfil their mobility needs, a university staff body is deemed to be open minded for sustainable travel options at a more than average scale, and many members of the university community have international biographies, so they might have had positive experiences living in countries where cycling is very popular despite mass motorisation.

Using the example of University College Cork (UCC), where the author has been working as Commuter Plan Manger for the last four years, this paper will not only describe ways to facilitate and promote cycling as a sustainable means of everyday

mobility but also discuss the limitations and difficulties in doing so both in and outside the campus boundaries. This case study is primarily based on personal experiences from daily work at UCC and from collaboration with many people in Cork, who are in one way or the other involved in cycling (e.g. members of the Cork Cycling Campaign, the City Council Traffic Division and others).

Cork City has a population of c. 120,000 with another 70,000 in the immediately adjoining suburbs (e.g. Douglas, Ballincollig, etc.). UCC is situated in an inner city location, about one to two kilometres southwest from the city centre. With staff of c. 2,500 and about 16,000 students, UCC is one of Cork's biggest employers and Munster's largest educational institution. It has a very compact campus that in its main parts stretches over half a kilometre, with some outlying parts at c. 1-2 km off the Main Campus. Its major part is along the banks of the River Lee and on a slope up to Cork's south side.

2 UCC'S COMMITMENT TO A GREEN TRAVEL POLICY

The University has committed itself to an active green travel policy. This process started in the late 1990s, when along with substantial expansions and increased traffic to and from UCC that followed a rise in student and staff numbers, the issue of commuting needed to be addressed. A Commuter Plan has formally been in place since 2005, aiming at a modal shift from the single occupancy private car towards alternative modes of transport: walking, cycling, public transport, car pooling, Park+Ride, Park+Cycle. Further, UCC has been offering its staff members access to car sharing since 2008 [1], as the first university in Ireland.
A full time Commuter Plan Manager was appointed in 2006 to manage and coordinate all different aspects of physical access, transport and commuting to UCC, to promote the various options of sustainable travel inside the University and to liaise with all parties involved in and outside the campus, with Cork City Council's Traffic Division being the foremost important partner.

Further, UCC was awarded the status of Green Flag Campus by An Taisce and the Foundation for Environmental Education (FEE) in February 2010, being the first third level institution worldwide to have achieved this status. This both student and administration based initiative focuses on various aspects, travel being one of them along with energy, waste and water.

3 FACILITATING CYCLING ON CAMPUS

3.1 On-campus infrastructure

A university seems to be the ideal place to promote cycling. An open minded and – presumably – more than average environmentally aware staff body meets a young student population with its traditional budgetary constraints. So what can a university do to actively encourage its population to cycle?

The very obvious is the provision of sufficient, fit-for-purpose and secure bicycle parking facilities on site. Today UCC provides bicycle stands for c. 850 bicycles around all parts of its campus. The majority of them are "Sheffield" type or similar hoops to lean a bike against from either side, letting the cyclists comfortably lock their bikes with the frame to the rack (figure 1).



Figure 1. UCC standard bicycle rack

When opening two new building complexes in recent years, UCC took the opportunity to provide room for ample bicycle parking from the start. In the older parts of the campus, however, the limited availability of space and other constraints sometimes still make it harder to identify suitable locations for additional racks. The cyclists' wish to park their bikes closest to the building where they work or study often leads to a parking demand

exceeding capacity in some locations, while many racks remain vacant in others. The provision of covered bicycle racks is not only a question of extra funding, but can often mean a challenge to the aesthetic appearance of the campus in places, and adequate design solutions might collide with budgetary constraints.

Apart from high quality parking, changing facilities for cyclists have become increasingly important, especially for cycling members of staff. While in the Brookfield Health Science Complex, which opened in 2003, existing showers may be used by cyclists, the opening of the new Western Gateway Building (home to up to 400 staff) in 2009 saw the installation of dedicated shower / locker facilities for cyclists from day one. Recently a set of five shower cubicles was retrofitted in an older building on the Main Campus. Along with large lockers, they will give staff members a chance to refresh and change clothing after cycling into work and before starting the working day.

3.2 Cycle-to-Work Scheme

Supporting staff members in the acquisition of a good bicycle is one of the clearest incentives that an employer can offer to encourage staff to cycle to work. As such, the Government's "Cycle to Work" tax incentive scheme, initiated in 2009, provides employers with an ideal tool for doing so. UCC adopted the scheme in September 2009. To date, hardly one year later, almost 200 staff members (meaning c. 8% of the staff body) acquired a new bicycle through UCC under this scheme.
In terms of providing the student body with a similar opportunity, UCC together with the Students Union is exploring the option of getting bicycle packages set up in a bulk order so as to realise substantial discounts. There are also attempts to facilitate a second hand bicycle market.

3.3 Information

Information about all means that are available to travel to UCC is provided on a comprehensive website section of the University's homepage ("Commuting, Access and Parking", http://commuting@ucc.ie). Among other topics, information about cycling related events in Cork is disseminated to staff and students, and through various promotion activities awareness is raised for cycling.

4 BEYOND THE CAMPUS FENCE – CYCLING TO UCC ON CORK ROADS

Although the University's immediate influence finds its limits at the college gates, it is outside the campus where the real challenges start. Before parking their bikes on the campus, people need to cycle to UCC on Cork roads. Feedback about the general condition of cyclists in Cork's road traffic is ambiguous. Experienced cyclists usually seem to get along with road traffic conditions quite well in general, and only tend to complain about specific danger spots. However, a common attitude among the general population is: *'I will be taking my life in my hands when I start cycling in road traffic'*. As a result many people refrain from doing so.

4.1 Challenges in Road Traffic

It might be interesting here to ask the reasons why. Is it because of drivers' inconsiderate behaviour? A lack of cycling skills and education or forgotten cycling habits and a lack of confidence? A road side cycling infrastructure which still holds lots of room for improvement or the multitude of dangerous surprises that road surface conditions might have in stock?
A fair mix of everything with a varying emphasis on one or the other aspect will come closest to the truth.

Inconsiderate Drivers

Regarding inconsiderate behaviour by many drivers towards cyclists, there is a somewhat simple and banal rule of thumb that gets quoted every now and again when getting reports from "cycling countries" abroad (e.g. The Netherlands, Denmark, Germany etc.): Safety in numbers! The more cyclists that drivers come across on the roads, the more aware of cyclists the driving population will become. And even better, the more that drivers also tend to cycle every now and again, the more aware they will be of cyclists' needs in road traffic.

Cyclists' Skills

Many people willing to cycle express their discomfort with cycling in road traffic. They might not have cycled in city traffic for years or decades, with the volumes of car traffic having dramatically risen since. Over the past two years, Cork City Council have offered free cycling training courses for adults to the general public on various occasions, which were widely advertised in UCC. These (usually one-afternoon) courses were given

by experienced cycling instructors and started in a park and on a quiet road nearby and ended with a guided cycle through busier city road traffic. The feedback used to be very positive throughout and will serve for more and more people taking the step and go out on the roads on their bike with more confidence.
The more people can attend such training courses, especially at an early age (e.g. when courses are offered in secondary schools), the more people will feel confident enough to use the bicycle in road traffic on a regular basis.

4.2 Cycling Infrastructure

Regarding road side cycling infrastructure, there is one general concession to be mentioned at the start: Yes, streets in Irish cities are often narrow, available space is limited and in many cases the roads' cross sections do not provide the space for additional cycle lanes along with two way car traffic.

But even though many people would call for "more cycle lanes", this should be translated to: *"Have a cycling infrastructure, as part of a hierarchic road network for all different road users"*. Catering for cyclists is not all about putting red paint on the ground. There is a comprehensive bundle of measures that can make city streets more pleasant and safe to cycle on.

Reducing the speed difference between a cyclist and motorised traffic by means of traffic calming (e.g. 30 km/h speed limits) will lead to higher safety and comfort. This will typically apply to residential roads that are part of a cycling route and cater for motorised traffic only locally, but may also be used in city centre streets to make High Street locations more accessible for cyclists (as planned for Cork City). Other measures include:

- Provision of direct enough alternatives to major thoroughfares through quiet parallel streets
- Combination of residential streets and wide footpaths offside roads to cycling routes
- Opening of suburban cul-de-sacs (where physically possible) for cyclists and pedestrians
- Opening of one-way streets to cyclists in the opposite direction, by means of a physically separated track, marked contra-flow cycle lane or by specific traffic signage ("no entry, except cyclists").

In the case of Cork City and the surroundings of UCC in particular, the road network has a number of constraints deriving from the city's topography. Western Road – right outside UCC – is the major trunk road towards the West, with hardly any alternative. Slopes between the River Lee and the hilly south side can be quite steep in places, still less however than on the city's north side, and a multitude of one way streets (either because of narrow cross sections or as a means of traffic management) very often impose major detours on motorists and cyclists alike with no distinction. While the former might be valid and intended for means of traffic management and calming for motorised traffic, the latter is a huge deterrent for promoting cycling as a fast and green alternative.

4.3 Opportunities in Cork for a network of cycling routes

But despite these constraints, there is tremendous potential in Cork to create a network of cycling routes combining all of the elements mentioned above. With the combination of (in major parts existing) more quiet residential roads, off-road 'greenways' and short stretches of contra flow cycle lanes in one-way streets – along with adequate sign-posting – there are good opportunities to create a skeleton cycling route network.

- Allowing contra flow cycling in wide enough one-way streets in some few key locations (e.g. Pope's Quay) can provide a fast, direct (and legal) link from UCC to the city centre and to Kent Train Station. This route would mostly run along the river banks and quays, so there would be no significant slopes involved
- Paving along with sign-posting of a (quite hidden) footpath along side a stream can provide the missing link for a south-western cycling route to UCC (Glasheen River between Glasheen Road and Magazine / College Road)
- Some improved road surface, a stretch of contra flow lane and some ramps to an existing footpath on a former railway track, along with adequate sign-posting, can create an excellent 5km high quality cycling route linking highly populated housing areas, an office and retail park (Mahon Point / City Gate office park) to city centre on a greenway (former Blackrock Railway line, Marina, Centre Park Road)

- A small number of short links for cyclists and pedestrians between crescent shape or cul-de-sac residential roads may provide a cycling route from highly populated Douglas into the city centre – or when cutting across the south side, to UCC, avoiding the very busy and narrow thoroughfare of Douglas Road.

These are only very few examples where small scale adjustments to the layout of existing roads and paths could make a difference for creating a more cycling friendly environment in Cork.

4.4 Suburban Road and Path Layout

The typical road layout in Irish suburbs usually does not favour cycling (and walking) over longer distances while avoiding busy main roads, as will be shown in the following example.

The Ballincollig Example

Situated about 5km west of UCC, Ballincollig (c.17,000 population) has become an important commuting town over the last couple of years and is home to a considerable number of UCC staff members and students. It basically stretches some three kilometres along an east-west main road, with lots of housing estates built in the recent past. Many of these estates follow the same principle as regards their footprint: Starting from the town's main road, one access road serves a large number of cul-de-sacs not allowing any traffic other than for local access to pass through, which is for a worthy cause. But at the same time, often the complete absence of any additional links for pedestrians or cyclists between these estates can be observed. In many cases, walls completely separate one estate from the other. This forms a number of isolated 'islands' within the suburban fabric, only connected to the outside world at one single access point. While this tree shape road layout serves the positive principle of (motorised) traffic calming, it forces pedestrians and cyclists to end up on the main road sooner rather than later, where they will often find themselves in an uncomfortable environment, primarily designed for high volume car traffic. This lack of permeability, which also imposes significant detours, denies cyclists and pedestrians the opportunity to travel longer distances away from main roads with significant volumes of motorised traffic on them. Figure 2 shows a part of Ballincollig, with the added lines highlighting the separation of neighbouring estates.

Ballincollig is linked to Cork by two cyclable roads: While the one can be characterised as a suburban thoroughfare, lit all the way but with a number of climbs and dips, the other is a 2km long straight, flat country road, with a 100 km/h speed limit and no lighting in parts (to date). It can be assumed that a safe and comfortable link to Cork together with an improved permeability of the town fabric can mobilise a huge potential for bicycle commuting to UCC.

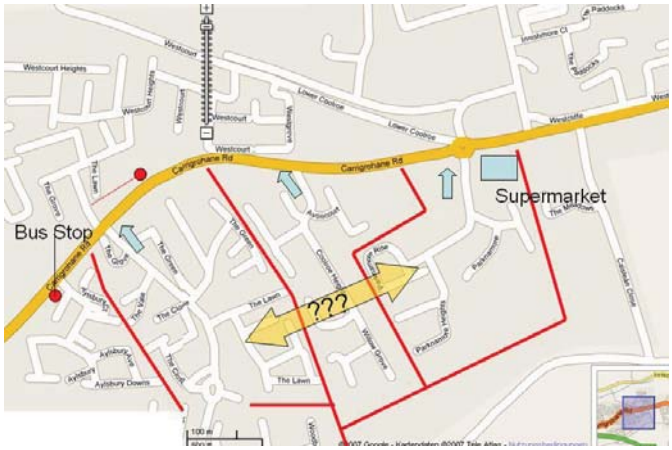

Figure 2. Estates footprint in Ballincollig West

This pattern of a non permeable layout of towns and estates can often be observed in the Irish suburban context, and must be regarded as one major impediment to cycling, leading to a high degree of car dependency at the very start of the journey. Another paper in this conference will examine the walkability of Irish suburbs in further detail. The knock on effects of such town layouts on the travel behaviour especially of children and the subsequent health effects have recently been described and criticised in a position paper published by the Irish Heart Foundation [2].

The Role of Local Authorities, Businesses and Developers

The local authorities (city, county and town councils) can and must play an important role in good and fit-for-purpose planning as well as for rectifying less fortunate results of same in the past. Local businesses as a major and influential stakeholder group must be taken on board as well as developers of housing estates and business or

retail complexes. Businesses will typically fear a loss of accessibility for their car driving customers in connection with traffic calming measures. But they must also be shown the opportunities that accompany an improved shopping experience, including a greater pleasure for shoppers of being in a less car dominated town or city centre. Studies have proven that local businesses benefit from a more pleasant shopping environment and tend to over estimate the importance of easy car access for their patronage.

Developers by nature will have other targets than a local council when building a new estate. But the local authorities hold the key to what will be built in their town or city, when they are to grant planning permission for a new development. It must be up to them to take active leadership in creating the town's road, foot and cycle path network layout. They should consider the planning process as a creative process rather than a formal act, in order to avoid towns and suburbs that look like a patchwork of isolated estates, almost chiselling car dependency in stone to the highest degree, as can often be observed as a result of less favourable results of past planning.
This train of thought has led a fair bit away from the immediate influence of the University in terms of cycling promotion. But it can be understood as the University's role as local stakeholder and bearer of a huge amount of knowledge to raise awareness for such contexts and interdependencies, both through research within the related faculties and disciplines and locally in the course of public consultation processes. Because: Staff and students who can leave their homes only by car are unlikely to arrive in college by bike.

5 THE UCC CAMPUS-BIKE SCHEME

Despite all efforts, there will always be a considerable number of university (staff) members who do not come to work by bicycle, because they need to drop their children at school, they live too far away to cycle in, or various other constraints. In order to give these people access to a bike during the day, UCC is in the process of establishing a communal bicycle scheme. This scheme called *"CampusBikes"* was proposed as a demonstration project under the Department of Transport's Smarter Travel Fund programme in September 2009, and UCC was granted significant funding for it. The project has a volume of €30,000, two-thirds of which funded through Smarter Travel for a duration of 18 months. At its pilot stage, the *CampusBikes* fleet will consist of 10 bicycles, located throughout the greater UCC Campus at five different locations. The bikes will be available to staff members for short term use during the working day, for travel between different parts of campus or within Cork City, primarily, but not only, for work related purposes.
The scheme can be regarded as a mini version of the Dublin Bikes (public rental) scheme, with some significant differences to be noted: It shall operate without an expensive background infrastructure, it will be free of charge and open to a far less anonymous, still limited target group. It will be designed for round trips only (no one-way bookings). The most significant difference, however, in legal terms will be the fact that the employer will provide bicycles to its employees for work purpose use, which leads to a different relationship between the user and the service provider.
CampusBikes will give UCC staff easy access to a bicycle in college, providing a new degree of mobility for short trips, faster than walking or driving, avoiding all issues of parking. It shall raise awareness for a green and healthy travel option and lower the threshold of using a bicycle.

The *CampusBikes* scheme is designed for an ongoing operation, once the formal 18 month pilot has ended, and may be extended to further user groups in UCC, namely to the student population (at this stage, charges will need to be addressed). The scheme shall serve as a demonstrator for any kind of campus, educational, health or business, as a strong emphasis is laid on its documentation and transferability. *CampusBikes* is planned to replace up to 200 motorised trips (car, taxi) per month, and to make cycling as easily accessible as possible, as a means of transportation, for a significant number of people, be they experienced cyclists or novices to the two wheels. With *CampusBikes*, University College Cork will bring cycling (back) to people's minds as a matter of cause in their every day mobility.

6 CONCLUSION

A university has many opportunities and means to encourage and facilitate cycling among its staff and

student body, ranging from provision of basic access and parking infrastructure to incentives for acquiring a bicycle, dissemination of information and raising awareness about the benefits. But providing a decent cycling infrastructure for getting to the campus and back is up to the local authorities. They are in charge for both soft measures (winning people's hearts and minds) as well as for hard measures, like substantial improvements for cyclists on their roads. The local councils need to take on this challenge and the university as a local stakeholder can support the council in this respect. And where there are institutional impediments for the councils to do so, the local authorities must be enabled to be a driving force in this process, and administrative structures and legislation should be subject to review in case. The Irish Government's National Cycling Policy Framework, published in early 2009, as part of its Smarter Travel programme, is an excellent basis for creating a more cycling friendly environment and for establishing a cycling culture comparable to other European countries.

In Cork City, there has been and continues to be a fruitful cooperation between the City Council Traffic Division and UCC (and other local parties involved) and a good climate to promote cycling. This is also manifested in Cork City's very ambitious bid to become a Smarter Travel Area, with substantial funding for sustainable travel projects from the Department of Transport. This is fully supported by University College Cork, and the prospects are good that in Cork, we can make a difference in the way we all move in our city, in a greener, healthier, more space and cost effective and future proof way.

ANNOTATIONS / REFERENCES

[1] Car sharing schemes consist of a fleet of cars for short term rental, based throughout the city (also known as "car clubs", not to be confused with lift sharing)

[2] National Heart Alliance and Irish Heart Foundation, *Building Young Hearts, Physical Activity, Young People and the Physical Environment*, April 2010

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THE POTENTIAL FOR ORIGIN-BASED MOBILITY MANAGEMENT PLANS (PERSONALISED TRAVEL PLANS) IN THE GREATER DUBLIN AREA

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ABSTRACT

Personalised Travel Planning, a form of mobility management planning targeted at the trip-origin (in other words at residential areas), has proved to be a reliable and cost-effective means of reducing car usage in favour of other more sustainable travel forms. These direct-marketing schemes, which target communities with individually tailored travel information materials, succeed in reducing car usage with no investment in hard infrastructure.

The concept, when subjected to rigorous academic and other independent scrutiny, has reportedly achieved consistent mode transfers away from car-usage of five to fifteen per cent. This has often taken place in low-density areas of high car ownership rates and results have been maintained over time. In Australia, every major city has commissioned personalised travel planning programmes. In the UK, the government has, on foot of successful pilot studies, recommended the implementation of such schemes across all local authorities. Recently, three "Smarter Travel Town" initiatives in the UK – where suites of "soft" transport planning measures were piloted – suggested that personalised travel planning can be a core and successful component of any such program.

This study seeks to assess the applicability of such concepts within the Greater Dublin Area. Initial evidence suggests the methodology is applicable with potentially high benefit : cost ratios. A pilot survey, undertaken as part of earlier research, revealed that within five selected newly developed areas individuals' response to the concept is comparable, if not more favourable to that revealed in other travel markets. A benchmarking study carried out in Drimnagh during March 2010 – as part of the Dublin City Council Smarter Travel Town bid – demonstrated high levels of community receptivity to such a scheme. The context and revealed market response indicates that such schemes are likely to achieve a successful outcome within Dublin. Indeed, one recent pilot, at Adamstown, yielded very positive results after a thorough programme was piloted to more than 200 households.

Assessment of the initiative in other markets suggests certain cautions. A groundbreaking UK study, "Smarter Choices", which thoroughly assesses all "soft", or behavioural transport planning initiatives in the UK, warns that such initiatives should only be implemented alongside complementary demand-management measures. Otherwise, gains in reduced congestion will only be lost to alternate users not targeted by the scheme. Nevertheless, the evidence suggests that Personalised Travel Planning, when combined with demand management and introduced to areas where available public transport capacity exists, has the potential to make significant impacts on car usage within the Greater Dublin Area.

Keywords: Personalised Travel Planning, Smarter Travel, Origin-based Mobility Management Planning

1 INTRODUCTION

This paper discusses the potential for Origin-based Mobility Management Planning in the Greater Dublin Area. By Origin-based Mobility Management Planning, it is meant to describe non-infrastructural (often described as "soft") measures, which can be applied to residential, or primarily residential areas to reduce the demand for travel and to promote environmentally sustainable travel behaviour. Mobility Management is an attempt at improving mobility by influencing behaviour and for this reason is often classified as a travel behavioural change initiative.

Mobility management has traditionally focused on the trip-end. Recent evidence strongly suggests that the most effective means of achieving sustainable target objectives is by targeting the trip-origin (residential areas). A number of methodologies have emerged based on this principle and some, in particular, have been shown to be very successful in other markets. These approaches, known as Personalised Travel Planning, involve programmes whereby individuals are contacted and provided

with tailored information to assist them in altering their travel behaviour should they so wish.

The first part of this paper describes a recently undertaken benchmarking study in Drimnagh, Dublin. Undertaken in March 2010 its aim was to pilot the initial stages of a Personalised Travel Planning (PTP) program and assess the potential for such a scheme in the area. The second part of this paper looks at the evolution of PTP and appraises the benefits and risks of the methodology as likely to be applied within Dublin.

2 PART I – DRIMNAGH SMARTER TRAVEL TOWN BENCHMARK PTP SURVEY

During 2010 Dublin City Council prepared a bid to have Drimnagh designated as a Smarter Travel town. Smarter Travel towns are areas where latest practices and investments in sustainable travel are piloted and reviewed. One of the initiatives being explored is a Personalised Travel Plan, whereby local people are encouraged to improve their travel behaviour via direct marketing.

As part of UniverCities (part of the Creative Dublin Alliance) and *Students Learning with Communities* (SLWC) initiatives, DIT School of Spatial Planning agreed to carry out a survey of the local community to gauge interest in and the likely success of such an initiative.

This was a door-to-door questionnaire survey and was carried out by second year BSc Spatial Planning and Environmental Management students during March 2010 as part of the Techniques II – Data Collection & Survey Methods module.

The DIT Programme for *Students Learning With Communities* supports staff and students engaging in community-based learning and research (also known as service-learning), and builds links with communities. *Students Learning With Communities* involves DIT staff and/or students working with community partners (local groups, not-for-profit organisations, etc) to develop real-life projects. Learning comes alive for the students as they work on these projects with real clients, applying their specialist subject skills, and receiving course credits for their work. The community becomes part of the teaching process and benefits from the students' work. These projects give all participants the opportunity to engage in critical thinking and to develop their social awareness. The Programme for *Students Learning With Communities* ultimately aims to energise participants to work for social change.

2.1 Study Area Profile

The study area is a mature, low-density residential suburb of Dublin. Public transport services to the area are good, including the Tallaght LUAS light rail line and the Crumlin Road QBC. The survey and proposed scheme represents an intervention in a mature low-density residential suburb with relatively high private car mode shares (55% per baseline survey).

The target area is characteristically low-density, fostering high car dependency. Infrastructure and public transport services are notoriously cost-ineffective in such environments. Yet Personalised Travel Planning has been demonstrated to be an effective tool for reducing car dependency and improving mobility with sustained results over time.

2.2 Survey Methodology

The survey was undertaken door-to-door on Thursday 4th March 2010 between 4PM and 8PM. While most surveys were collected during this period, a small number were collected during the subsequent weekend. Conditions were fair for the duration of the survey.

233 households were surveyed. This represents approximately a 5% sample of the target neighbourhood, which itself consists of 4,780 houses.

The surveys were carried out by 5 teams of two students each. Each team was designated a locality within Drimnagh Integrated Area Plan and required to collect 50 surveys. Group E (Slievenamon) gathered 33 surveys. The localities were discussed with local community representatives at a forum organised by Dublin City Council to make sure that they were a representative sample of the wider area.

2.3 About Personalised Travel Planning

Personalised Travel Planning (PTP) schemes aim to encourage increased cycling, walking and public transport usage among communities. PTP is a direct marketing scheme which targets communities with tailored, individualised information to reduce car dependency and promote public transport and cycling/walking. PTP is best suited to low-medium-density suburban and semi-suburban residential neighbourhoods, where sustainable travel gains are otherwise difficult to achieve. The proposed PTP in the Drimnagh IAP area can test the methodology with local improvements to cycle / pedestrian infrastructure.

Personalised Travel Planning normally comprises a three stage process: -

- Initial benchmark travel survey
- Household Marketing Campaign
- Ongoing travel surveys

The PTP scheme is an awareness raising exercise targeted directly in the community. A benchmark travel survey is carried out to profile existing behaviour and assess the potential for change. An individualised marketing campaign can then deliver tailored information to all households expressing an interest in the scheme. Evidence suggests that through direct marketing awareness raising households will modify their travel behaviour towards more sustainable practices. Ongoing travel surveys are finally conducted to monitor progress and benchmark the performance of the programme.

Various independent UK (UK Dept. for Transport, "Smarter Choices", 2004 / Merseyside Pilot PTP 2009 / Sutton Pilot PTP 2009) and Australian evaluations suggest that PTP typically delivers 5-15% sustained mode shift away from private car towards walking, cycling and public transport with no required investment in services or infrastructure and also suggest positive cost : benefit ratios. (www.sustrans.org.uk/www.smartertravelsutton.org /www.travelsmart.gov.au)

In planning terms, the benefits of PTP schemes are considered to be threefold. Firstly, Sustainable Communities can be protected and developed fostering improved health; carbon footprint reduction; improved social cohesion. Secondly, Sustainable Transport is a natural aim of the program creating a reduction in traffic levels; public transport mode share increase; increased cycling / walking mode share; reduced car dependency. Finally Sustainable Planning is pursued through finding a cost-effective methodology for reducing car dependency in low / medium-density residential environments.

2.4 Main Survey Findings

The entire survey, some of which examined variances between areas within the study area, will not be described here. Below, however, are the responses to and analysis of the most pertinent aspects of the survey inquiry. The analysis compares the results with typical or expected results based on benchmarking studies and outcomes from other markets. These outcomes and their limitations will be discussed in greater detail in Section II of this paper (below).

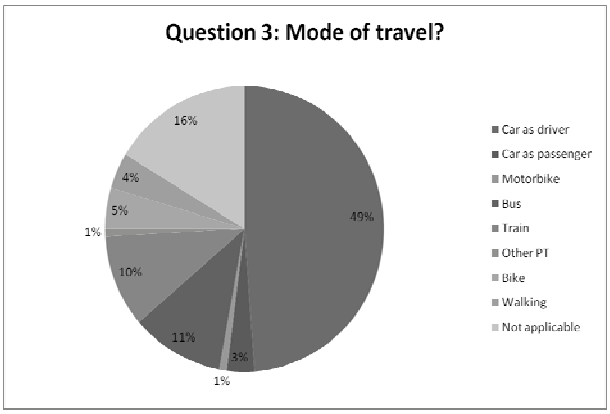

Figure 1. Mode of travel to place of work or education

- 54% of respondents travel to work or education by car
- 10% of respondents travel to work or education by rail
- 11% of respondents travel to work or education by bus
- 9% of respondents travel to work or education by bicycle or foot

Travel behaviour varied quite significantly between localities, with a higher car mode share in Comeragh Road (70%) than Brickfields Park (40%). Not applicables were made up of a relatively high number of taxi drivers and also out-of-work people. Rail was highest in Galtymore / Cooley Road (22%) but relatively consistent elsewhere (8 – 11%).

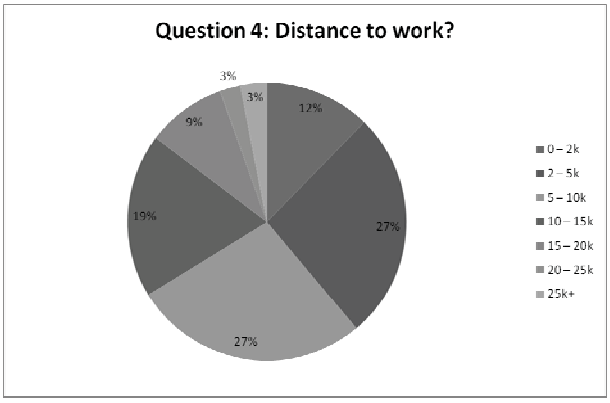

Figure 2. Distances travelled to work

- 12% of respondents travel 0 – 2km to work or education
- 27% of respondents travel 2 – 5km to work or education
- 27% of respondents travel 5 – 10km to work or education
- 34% of respondents travel more than 10km to work or education

Distances travelled to work in the area are relatively high, reflecting perhaps its suburban nature distant from main centres of employment. 39%, however, travel less than 5km and could be targeted for potential transfer to walking or cycling modes.

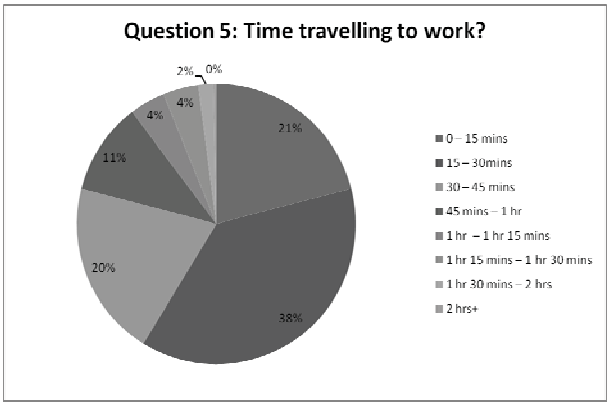

Figure 3. Time travelled to work or education

- 21% of respondents travel under 15 minutes to work or education
- 38% of respondents travel 15 – 30 minutes to work or education
- 20% of respondents travel 30 – 45 minutes to work or education
- 21% of respondents travel more than 45 minutes to work or education

Times travelled to work or education could be considered reasonable in the context of the Greater Dublin Area but are nonetheless significant. 41% of respondents take longer than 30 minutes to get to work or education. Long journey times, especially by car, have the greatest potential for mode transfer as people generally value personal time highly.

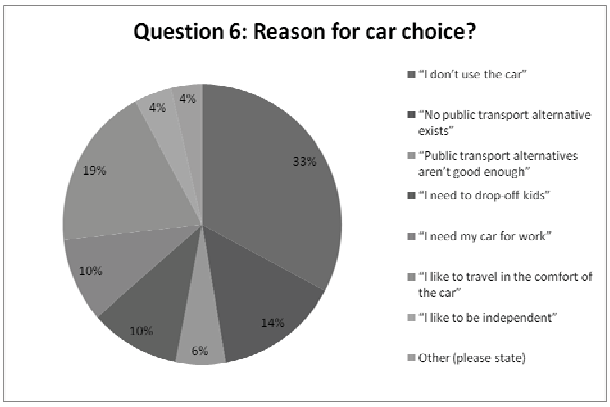

Figure 4. Reason for car choice

- 33% of respondents stated they do not use the car on a normal basis
- 20% of respondents stated public transport alternatives are either too poor or absent
- 20% had an absolute necessity to use the car
- 27% stated the car as a preference only

Only 20% had a necessity to use the car. Benchmarked against other markets where PTP schemes have been carried out this is quite a typical situation. Using the PTP methodology a significant percentage of the community (47%) could be targeted for mode transfer. PTP schemes are generally successful where 40% or more have the potential for change.

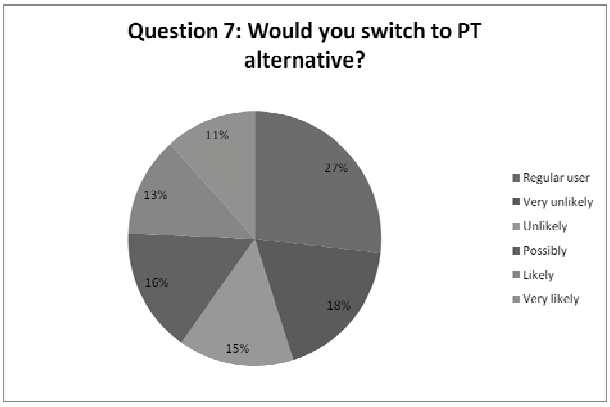

Figure 5. Willingness to switch to a Public Transport (PT) alternative

- 27% of respondents stated they regularly use PT
- 33% of respondents stated they were unlikely or very unlikely to opt for PT
- 40% of respondents indicated at least some willingness to opt for PT

Benchmarked against other markets and PTP schemes, a low number of respondents (only 33%) stated they were unlikely or very unlikely to opt for PT. This is again encouraging for PTP within Drimnagh. Using the PTP methodology a significant percentage of the community (40%) could be targeted for mode transfer specifically to PT. This does not include potential for transfer to non-motorised transport, which often is the highest beneficiary of changed behaviour.

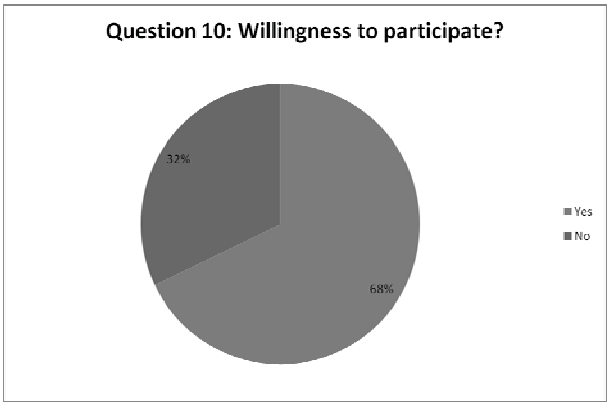

Figure 6. Willingness to participate in a Personalised Travel Planning (PTP) scheme

- 68% of respondents stated a willingness to participate in a PTP scheme
- 32% of respondents stated no willingness to participate in a PTP scheme

Each respondent had the PTP Concept briefly explained to them. On the basis of this they were asked if they would be willing to participate in such a scheme if carried out in their community. Over two thirds of the surveyed community indicated a willingness to participate. The response rate varied greatly between localities (see appendix), with a very positive response in Comeragh Road (78%) and less so in Brickfields Park (47%).

Benchmarked against PTP surveys in other markets, both within the Greater Dublin Area (GDA) and internationally, this is a very high positive response rate (68%). Similar surveys within the GDA have yielded a positive response rate of 52-64%. The premium achieved in Drimnagh may be as a result of strong community cohesion mixed with recent participatory planning and outreach activities by Dublin City Council. PTP schemes in other markets have proven successful where 45% or more have indicated willingness to participate.

2.5 Other PTP Pilot Initiatives in the Greater Dublin Area

A similar study to Drimnagh was carried out in Glasnevin during 2009, also by students of the BSc in Spatial Planning at DIT. Glasnevin is a similarly structured neighbourhood to Drimnagh with a low-density residential profile. The study revealed very similar results to Drimnagh and will not be discussed in-depth in this paper. Car mode share was 62%. "Potential for change" levels of up to 51% were recorded and a "willingness to participate" response of 64% was returned.

In order to understand people's likely responses to a PTP in newly developed areas, a household survey was undertaken in five framework development areas within the GDA during 2006. The aim of the survey was to assess the potential demand for Personalised Travel Planning within such areas. Surveys took place within the following areas: -

- Pelletstown
- Cherry Orchard
- Tyrrelstown
- Ongar
- Smithfield

Each of the above are recently occupied areas developed on the basis of framework development plans. They represent a reasonable distribution in terms of city centre / brownfield / greenfield and inner/transitional/outer locations. A number of them also have developer-funded public transport service agreements, the most successful of which is Pelletstown, where the developer has funded the extension of an existing route into the site with a 10-minute headway.

Surveys were hand-delivered to household letterboxes. A stamped addressed envelope was enclosed to encourage a good response rate. Survey distribution was done in the evening time so that it was possible to tell whether houses were occupied or not.

220 surveys were distributed. 64 surveys were returned. This represents a response rate of 29 per cent, which is considered reasonable in survey response terms. Each survey queried the behaviour and opinions of up to two adults within each household. In total, then, 115 individual responses were received. While this is a relatively small sample size, given the resources, timeframes and scope of this thesis dissertation a larger sample was impractical. However, the response may be considered significant enough to be considered as a robust pilot study into Personalised Travel Planning within new framework development areas.

Responses were good from four of the five areas. Only Smithfield returned a low response (4 surveys returned out of 40 issued). This may be attributable to the fact that no door letterboxes were available and it was not possible to establish clearly whether homes were occupied or not.

The survey objectives were four-fold. Firstly, a number of questions were put to profile the respondents. Secondly, a number of questions were put to establish existing behaviour. Thirdly, a number of questions were put to establish the Potential for Change of the respondents. Finally, respondents were asked directly whether they would be willing to participate in a Personalised Travel Planning programme.

Respondents comprised a typical profile of newly developed areas, with a high level of professional employment and reasonably high-income levels. It was interesting that only 7 per cent of households did not possess a car. Given the large size of houses, it is likely that many of the households contained families.

61 per cent of respondents travelled to work by car. 22 per cent used public transport, while 6 per cent walked or cycled. 24 per cent of respondents travel a distance of under 5 kilometres to work. 87 per cent of respondents take less than one hour to travel

to work. Similar profiles to those undertaken within the base survey were observed. One notable difference is the significantly lower level of car-usage from Pelletstown. While the sample size is much smaller, this would suggest that the recently improved bus and rail services are having some effect.

The main reasons given for car usage were lack of realistic alternatives. Half of the respondents indicated that if a realistic alternative was available they would consider using it. Also, the proportion of respondents who had an identifiable reason for car-dependency other than lack of choice was very low (20 per cent). A further 10 per cent chose car travel based on personal preference. These may or may not be categorised as having potential for change. Either way, the survey indicates that the Potential for Change could be between 49 per cent - 59 per cent. This is higher than what is normally recorded within other markets, where 40 per cent is considered a typical response rate.

Peoples opinions of service levels were relatively benign, with reasonably high levels of approval for public transport quality as well as the quality of facilities for cycling and walking. There was a clear and (somewhat contradictory) disapproval of the level of available alternatives within the local area. The lowest level of disapprovals came from Pelletstown and Ongar, both areas where recent high-frequency bus services were put in place.

When asked directly whether or not respondents would like to participate in Personalised Travel Planning, 52 per cent said yes. This is a slightly higher rate than is generally experienced from pilot studies in other markets where interest levels of 40 - 50 per cent are considered typical. This is an encouraging indicator given a number of factors. The respondents were given a very brief written explanation of what Personalised Travel Planning involved. Respondents had just completed a questionnaire and therefore may have been affected by survey-fatigue. Respondents would also have been unaware of the strong incentivisation typically associated with Personalised Travel Planning initiatives.

Some level of skew may exist, however, given that the overall response rate was 28 per cent. Respondents may have an inherent interest in or be biased towards the concept. Such potential for artefacts are inherent in all surveys and equivalent effects are likely to be present in comparable surveys in other markets, so it is likely that the positive response can be interpreted as significant.

The survey undertaken was a small sample size, which is understandable given the scope of the study. However, it is considered large enough to form a robust pilot survey and it should be noted that pilot surveys have played a significant role in the evolution of Personalised Travel Planning programmes.

Observed behaviour from the survey was broadly in line with what had been recorded in the same areas in 2002, although the sample size restricts the level of significance that can be attached to such results. Whereas, for example, in the 2002 survey 63% travelled to work by car across the five study areas, in the 2005 survey 64% travelled by car.

Overall, the results are generally positive towards the concept of Personalised Travel Planning. The Potential for Change and Willingness to Participate, two key factors in the success of Personalised Travel Planning, measured higher than what is typically achieved in other markets where the scheme has been successful. While the overall sample was small the results are favourable towards the concept and would indicate, at least, that further more in-depth market research is worthwhile.

An important recent pilot study has been undertaken by South Dublin County Council at Adamstown (South Dublin County Council, 2010). A full PTP scheme was carried out targeting 213 households. Door-to-door contact was made with 84% of participants and car use in the area is 62%. Over the course of the study 59% of respondents said they had made some behavioural changes with 35% saying they would maintain their behaviour on a regular basis. The scheme incorporated many typical PTP measures including travel packs, pedometer challenges (considered to be one of the most successful components), door-to-door visits by representatives of the scheme and sample public transport tickets. The scheme, while relatively small in nature, is the first fully executed PTP exercise in Ireland. The result of the scheme appears to be exceptionally high and corroborate the results of pilot benchmarking exercises described above. This is an important development as it provides further vital evidence that PTP can deliver a high return on investment in the Dublin context (South Dublin County Council, 2010).

Results of benchmarking schemes in Drimnagh, Glasnevin and several new framework areas in the GDA have suggested strongly that PTP programmes are likely to exceed the results returned from other markets where the methodology is well established. The Adamstown

exercise provides the first hard evidence that this may indeed be so (South Dublin County Council, 2010).

3 PART II - A REVIEW OF PERSONALISED TRAVEL PLANNING PROGRAMMES INTERNATIONALLY

3.1 Introduction

Personalised Travel Planning initiatives are becoming increasingly widespread and the extent to which they are being analysed and debated is similarly increasing. While the earliest studies were undertaken in Germany its widest application has probably been in Australia where it has been deployed at a reasonably large scale (Brog, 2005).

In the UK the environmental transportation consultancy, Sustrans generated interest in the topic by undertaking a number of small scale studies in Gloucester and Frome in 2001 (LTT, 2005a). This led to the Transport for London Travel Options initiative, which aims to provide easy access to local travel information. A Transport for London Personalised Travel Planning initiative involving 4,000 households was undertaken in 2001, while the Living Change scheme by the Scottish Executive also involved 4,000 households (Department for Transport, 2004a). A Department for Transport programme of 14 pilot projects was also undertaken across the UK including target areas of up to 18,000 residents in some cases (Department for Transport, 2005a). The Smarter Choices study provides in-depth assessments of a sample of Personalised Travel Planning initiatives and some overview of the majority of those that have taken place.

More recently, the Department sponsored three "Smarter Travel" Towns, Peterborough, Darlington and Worcester. The Smarter Travel Towns piloted a suite of behavioural travel planning measures including personalised travel planning. The results from some of the towns have recently been published and high rates of return, in terms of mode transfer, were recorded, especially for PTP initiatives (Department for Transport, 2010).

There is also considerable case study material from Australia and other markets from the various consultants behind each scheme (www.patrec.org; www.socialdata.com.au; www.sustrans.org.uk).

3.2 Fremantle, Australia

A Personalised Travel Planning scheme using the Travelsmart methodology was undertaken in Fremantle, Western Australia (Socialdata, 2003b). A final report including evaluative data was published by the Department of Planning and Infrastructure in October 2004. The scheme was directed at a total of 17,000 residents representing 71 per cent of the population of this suburban city within the Perth built-up area.

The results of the evaluation survey declared a 12 per cent reduction in car-as-driver trips, a 13 per cent increase in public transport trips, a 25 per cent increase in walking trips and a 38 per cent increase in cycling trips. Overall, the total private car mode share reduced from 75 per cent to 70 per cent while alternative modes of transport increased from 25 per cent to 30 per cent.

Following the initial contact phase, households were segmented into Regular User (25 per cent), Interested (48 per cent) and Not interested (27 per cent). During the scheme a total of 4,901 households expressed an interest in receiving information. A total of 3,500 travel packs were distributed.

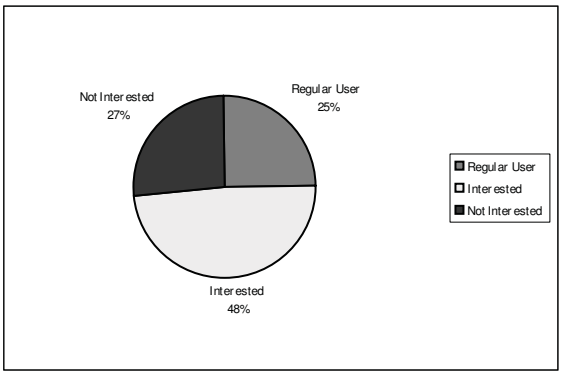

Figure 7.Segmentation of Fremantle Surveyed Households (www.socialdata.com.au)

As part of the scheme 143 bus stop specific timetables were devised and distributed to households. Other marketing materials distributed included: -

- A local area access map, showing bus stops, walking and cycling routes and local facilities
- Tickets and fares guide
- Bus stop specific timetables
- Standard timetables
- How to save money with Transperth Brochure
- Accessible travel brochure
- Brochures on cycling
- Cycle route maps
- Discount card from 4 local bike stores

- Guide to walking
- Walking maps and local walking event information
- Travel in Perth: facts and myths brochure

Of those who cited themselves as Regular users of an existing alternative to the car, 1,493 households or 84 per cent declared themselves interested in receiving further information. The remainder 276 were issued with a reward travel pack in line with the principles of the Travelsmart scheme.

Those regular users who expressed an interest, along with the Interested population segment were issued with service sheets to define what areas they were interested in receiving information. 11 per cent requested public transport-only information. 11 per cent requested only walking and cycling information. 78 per cent requested information pertaining to two or more modes. In total 65,000 items of information were issued. Much of this was issued by mail, but over 3,000 travel packs were distributed by bicycle couriers. According to the report, the wallet sized personalised local timetable proved to be the most popular item overall.

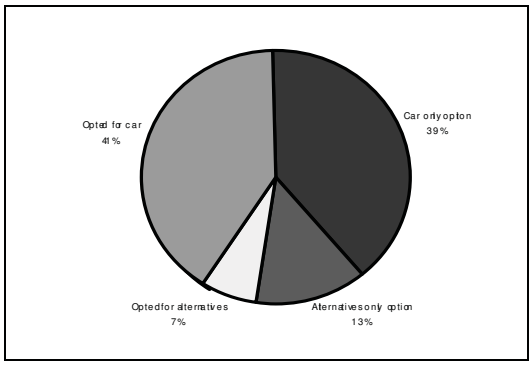

Figure 4.2: Potential for Change among Surveyed Users in Perth, Australia (source: www.socialdata.com.au)

3.3 Smarter Choices – a Comprehensive Review of Behavioural Transport Planning in the UK

The Smarter Choices - Changing the Way We Travel study represented a watershed in thinking within the UK towards Personalised Travel Planning and other behavioural travel planning measures (LTT, 2004a; Department for Transport, 2004a). Firstly, based on a comprehensive and exhaustive assessment of travel planning initiatives, the report concluded that significant mode transfers were attributable to behavioural travel planning and that they were cost effective. Secondly, the report was influential in kick-starting a range of centrally-funded initiatives, including Personalised Travel Planning ones. It further led to the introduction of behaviour-side initiatives into transport policy, again, including Personalised Travel Planning ones (LTT, 2005a; Department for Transport, 2004b; 2005c; Wilson, 2005).

The Smarter Choices report forecasts that, with a coordinated and integrated introduction of travel planning measures as appropriate, a reduction in peak period urban traffic of about 21 per cent could come about. According the study, the cost of implementing such "soft" initiatives is about 1.5p per kilometre; whereas the estimated benefit to the economy per 1km of congestion removes is 15p. Thus every £1 spent on well-designed soft measures could bring about £10 of benefit in reduced congestion alone.

As regards Personalised Travel Planning, Smarter Choices was no less thorough than with the assessment of other measures. Smarter Choices looked at all of the initiatives carried out within the UK and the bulk of those carried out in other markets. Notwithstanding some reservations about the independence of the evaluative process utilised within Personalised Travel Planning, Smarter Choices concluded broadly that Personalised Travel Planning had potential to deliver significant mode transfer and represented value for money: -

> *…results so far available suggest that Personalised Travel Planning may lead to reductions in car driver trips of 7-15 per cent amongst targeted populations in urban areas.*

According to the study a coordinated delivery of soft-factor interventions could lead to a reduction in peak hour traffic of about 21 per cent. The Smarter Choices report concluded overall that any such behavioural initiatives should not be implemented in isolation of a complementary set of demand management measures.

> *These projected changes in traffic levels are quite large (though consistent with other evidence of behavioural change at the individual level), and would produce substantial reductions in congestion. However, this would tend to attract more car use by other people, which could offset the impact of those who reduce their car use unless there are measures in place to prevent this.*

> *Therefore those experienced in the implementation of soft-factors locally usually emphasis that success depends on some or all of such supportive policies as re-allocation of road capacity and other measures to improve public transport service levels, parking control, traffic calming, pedestrianisation, cycle networks, congestion charging or other traffic restraint, other uses of transport prices and fares, speed regulation, or stronger legal enforcement levels.*

Such an approach is equally likely to apply to Personalised Travel Planning programmes as any other behaviour-side transport planning measure.

3.4 Evaluation of Personalised Travel Planning Initiatives

The Smarter Choices report points to a number of areas of concern facing Personalised Travel Planning evaluation. Firstly, differing methodologies have been developed that have all been categorised as Personalised Travel Planning in one form or another. However, the differing systems have inherently different evaluation frameworks. This affects the extent to which such results can be compared. Nevertheless, quantitative and subjective assessment of the results combined with the methodological framework strongly indicates that those initiatives based on individualised marketing tend to be the more successful. While the Smarter Choices report concludes that merit is to be found in Personalised Travel Planning in general, it is implicit that individualised marketing programmes have a wider applicability and have, thus far, demonstrated higher success rates.

A further issue that arises is one of objectivity. Most evaluation is carried out by the first party consultants themselves. Certain consultants have also been decidedly evangelical about, particularly, individualised marketing programmes. These programme reports are often published freely on the internet as part of the scheme. This no doubt contributes to the public awareness of the programme, an inherent element within the methodology itself. It also makes a lot of data readily available for assessment. Nevertheless, there is a clear need for objective criticism of the programmes. The programmes could benefit by a higher level of third party independent evaluation, a principle conclusion of the Smarter Choices report. Nevertheless, the conclusion of the Smarter Choices report is that: -

> *Bearing in mind these issues of data validity, (which, incidentally, may also apply to a greater or lesser extent to the monitoring of other soft factors), results so far available suggest that personalised travel planning may lead to reductions in car driver trips of 7-15 per cent amongst targeted populations in urban areas (according to trials in Germany, Australia, USA and the UK), with rather lower reductions in car driver trips (2-6 per cent) reported from a smaller number of more rural trials.*

3.5 Alternative Approaches to Evaluation

The conclusions of the Smarter Choices report while positive, given its thoroughness and strong empirical approach, are not without significant caveats. In the first instance the report is very conclusive that "soft" measures are likely to be of no material benefit unless accompanied by meaningful "hard" measures, in the form of a complementary programme of demand management, service level improvement or other investment in planning and infrastructure. It also iterates strongly that evaluation should be undertaken independent of the lead-implementing agents. This appeal for an objective and independent auditing process is a strong theme in the Personalised Travel Planning debate in Australia. Other concerns have also been voiced as to the validity of claims made by Travelsmart proponents (Morton et al, 2005; Richardson et al, 2005b; Stopher et al, 2005b).

It may be tempting to suggest that the enthusiasm with which Travelsmart has been adopted as a core part of national and regional travel policy is in itself an indicator of success. Travelsmart initiatives have now been adopted in all major cities in Australia with funding assistance from central government (Morton et al, 2005; www.travelsmart.com.au). Some commentators, however, have raised concern that Personalised Travel Planning schemes are seen as "something for nothing" whereby, at relatively low cost, transport authorities can achieve meaningful dents into car mode shares without any investment in infrastructure or services (Morton et al, 2005). The

implicit suggestion here is a shifting of responsibility from the agencies responsible for transport planning onto the users of transport services.

This seems a highly plausible concern and theory dictates that any such gains would quickly be negated in any instance as alternate travellers use up whatever road capacity was freed up by the Personalised Travel Planning programme. In this instance the warnings of the Smarter Choices report authors are reinforced and it must be strongly put forward that Personalised Travel Planning should form part of an integrated transport strategy that involves infrastructural, operational as well as marketing components.

Morton and Mees, in particular, challenge the validity of the Travelsmart claims (Morton et al, 2005). In a considered analysis of the psychology of Personalised Travel Planning participation the potential for data contamination is highlighted. In the target sample groups, the authors point out there are a number of inherent conflicts of interest that may skew the data and lead to false results. The results of the scheme are based on certain predications, the main one being that "public transport is better than I thought it was once I tried it". But there are also certain expectations of the initiative and likely respondents often act as "good subjects", or ones who wish either to impress or have a personal interest in a positive outcome. This leads to what are known as "artefacts", another way of saying a "self-fulfilling prophecy", whereby the observation of a study group itself alters the likely outcome of the study. These are important concerns and there is some evidence to suggest that they are occurring phenomena within the Travelsmart framework. These are also, however, concerns that ought to be associated with any sampling study and their discussion only underlines the importance of considering them in relation to Personalised Travel Planning studies. The authors correctly conclude, however, that objective, independent evaluation is the only framework within which Personalised Travel Planning can be assessed.

A number of other studies have expanded on this theme and examined ways in which Personalised Travel Planning can be independently audited (Richardson et al, 2005b; Stopher et al, 2005a; 2005b). One particular approach is the use of panels in scheme assessment. A popular methodology within public transport market analysis, panels are based on a targeted sample study group who are invited to act as respondents over a long time-frame. New members are co-opted onto the study group as old members decide to leave, thereby ensuring a reflection of the sampled population. In this way, the impacts of schemes can be studied in considerable detail. The panel approach has limitations, most particularly in relation to the size of the sampled population and the obvious risk of participation itself leading to skewed results through enhanced involvement and awareness.

An alternative approach is the use of corroborative evidence to validate Personalised Travel Planning initiatives. A study in Darebin, Melbourne used a combination of background data sources to verify results of a local Personalised Travel Planning initiative (Stopher et al, 2005b). The corroborative evidence confirmed mode transfer rates close to what the Personalised Travel Planning evaluation study itself revealed. Traffic count data indicated a 3 per cent reduction in car trips within the study area. Ticket validation data, recorded by individuals boarding public transport using smartcards revealed a 4/5 per cent increase in boardings. A similar rise in ticket sales was recorded in information also received from the local transit authority. Finally, independently monitored customer satisfaction surveys showed a 3 per cent increase in public satisfaction with local transit services.

Table 5.1: Darebin Corroborative Evidence (Source: Stopher et al, 2005b)

Data Source	Impact	Effect
Traffic Count Data	- 3%	Reduction in car trips
Ticket Validation Data	+ 4% / 5%	Increase in passenger boardings
Ticket Sales	+ 4% / 5%	Increase in sales
Customer Satisfaction Survey	+ 3%	Increase in satisfaction with transit services

3.6 Relative Impact by Mode Share

In almost all schemes, the greatest relative mode transfer was in favour of walking trips (Brog, 2005; Tideman, 2005). This was reflected in the number of behavioural switches completely over to walking or to walking and public transport. Figure 5.2 shows how mode transfers of 2-4 per cent overall are typically recorded.

This suggests that one of the main beneficial impacts of the scheme is on health levels among the target population. This is reflected by several cost-benefit analyses that attempt to measure these benefits (Socialdata, 2003a; 2003b). In several of the schemes, the effect which information regarding the benefits of walking had on individual health was remarked upon (Corpuz et al, 2005; Sustrans, 2004a; 2004b). The logical extension of such an argument is that Personalised Travel Planning should involve some input or support from local or regional health authorities who would lend weight to marketing initiatives and would themselves benefit from reduced healthcare burdens.

James also analysed the impact of Personalised Travel Planning schemes undertaken in the Perth area on public transport patronage (James, 2004). By assessing ticketing records, the evaluative surveys conducted following the schemes delivery could be cross-checked. Tangible increases in ridership were recorded in each target area examined, which included South Perth (17 per cent increase), Cambridge, Perth (11 per cent increase), Marangaroo, Perth (5 per cent increase) and Fremantle (12 per cent increase). The lowest increase was in Subiaco, Perth where a 4 per cent increase was recorded. This was after a 15 per cent reduction in public transport operational capacity in the area during the programme, suggesting a net possible increase of up to 19 per cent. The use of public transport ticketing records offers a useful independent evaluation and auditing tool, something that will be discussed in greater detail below.

Table 5.2: Effects of Individualised Marketing Initiatives in other markets (Source: Department for Transport, 2004)

	Control	Travelsmart	Fall in Car Usage
South Perth	60%	52%	-14%
Nurnberg	44%	38%	-14%
Goteburg			-13%
Viernheim			-12%
Brisbane			-10%
Portland			-8%
Kassel	48%	44%	-8%
Cambridge	60%	56%	-7%
Marangaroo			-4%
Breisgau	44%	43%	-2%

Tendency Towards The Smarter Choices report observed potential improvements to off-peak public transport patronage. In Nurnberg and Kassel, 70 per cent of behaviour change in favour of public transport was accounted for by shopping and leisure trips. While this suggests that the impact on peak-hour traffic is relatively lower, increased capacity utilisation is a considerable incentive to public transport service providers. In any case, overall peak hour car-as-driver trips are known to have been reduced in both Kassel (6 per cent) and Nurnberg (14 per cent) (Department for Transport, 2004a).

Local facility utilisation was also improved in a number of studies. Several of the schemes cited benefits to local businesses, both in terms of increased footfall, and lower congestion levels as net benefits of the scheme (Sustrans, 2004a).

3.7 Self-reinforcement

One particular feature among a large number of Personalised Travel Planning schemes is a tendency towards self-reinforcement. The overall assessment of Personalised Travel Planning initiatives, particularly those tending towards an individualised marketing approach, delivers a clear picture of success. What is remarkable in a number of schemes where continuing assessment took place was that mode share figures in the targeted areas continued to improve over time. This was in the absence of continued investment in the scheme and in comparison to neighbouring, control-group areas where the scheme was not carried out (Goulias, 2001; Department for Transport, 2004a; Stopher et al, 2005; Tideman, 2005).

James, in an independent assessment of the Perth pilot scheme, showed how the impacts of the scheme had been maintained two years after the programme had been delivered (James, 2004). Studies in Nurnberg and Kassel indicated sustained impacts 2 and 4 years later respectively.

3.8 Targeting Areas for Personalised Travel Planning

One final issue to be addressed regarding evaluation is the type of areas where Personalised Travel Planning is more or less likely to be successful. Interestingly, one of the least successful schemes was that conducted in Lambeth, London. Mode transfer rates achieved were low, as was the level of public interest in receiving information and incentives. This was possibly attributable to the absence of tailored incentives and information,

unlike other individualised marketing programmes. Nevertheless the results from this low car-use, high-density urban are that is comparatively well served by public transport is in contract to the results reported by consultants in other dissimilar places (Department for Transport, 2004a).

By comparison, in Gloucester, where car ownership was considered high by the local authorities and levels of congestion low, a significant level of sustained mode-transfer was achieved (Sustrans, 2004a). The evidence from these and other studies suggests that the Personalised Travel Planning approach is a good fit for medium-low density suburban areas, provided some potential for mode transfer to an accessible alternative exists.

The Smarter Choices report, based on its comprehensive assessment and case study interviews of all schemes within the UK, puts forward a list of likely relevant factors: -

- A recognition in the community concerned that there are traffic problems
- A fairly discrete and self contained community, with reasonable local services and facilities (not just a dormitory or satellite suburb)
- A reasonable level of public transport (and, ideally, some recent improvements in services)
- Some excess capacity on public transport
- A reasonable quality of environment for walking and cycling, including lower speeds and a people-friendly street scene
- Support from the local authority and other key partners, including public transport operators

Evidence from the Smarter Towns schemes, not addressed by the Smarter Choices study (the Smarter Towns initiative came about as a consequence of the Smarter Choices report) would also suggest that effective Land Use and Transportation Planning can influence the likely success of Personalised Travel Planning programmes (LTT, 2005a). Analysis of the three study areas indicated a correlation between the proportion of trips less than 3km and the potential for change. This is supported by results from other programmes where walking was seen as the biggest potential for mode transfer. The principle of locating employment uses in relative proximity to residential areas is now well recognised and an ever-increasing priority in area planning. The evidence from Personalised Travel Planning thus far serves to underline its importance in engineering the sustainable city. Ironically, it is the now discarded phenomenon of suburban, segregated land-use planning inherited from the garden city movement that can perhaps most benefit from the Personalised Travel Planning concept.

4 CONCLUSION: PTP IN DUBLIN – A WORTHWHILE INITIATIVE?

4.1 Evaluation Issues

The emerging evidence from an increasing library of scrutiny is that Personalised Travel Planning is an effective method for reducing car-usage in the long term and that it is justifiable on cost grounds (Department for Transport, 2004a; 2005a; Cohen, 2005). Furthermore, most of the available research suggests that there are considerable intangible benefits to community-health, local business and the environment that these should be factored into benefit-cost calculations. This evidence is supported by the rate at which the concept is expanding. Most major Australian cities now budget for ongoing Personalised Travel Planning programmes. In the UK it has been adopted as part of national strategy and extensive funding of initiatives has commenced. Personalised Travel Planning has bee successfully deployed in the US, Scandinavia and continental Europe (Brog, 2005).

Some criticism of Personalised Travel Planning schemes has come about, particularly within Australia, where the concept is perhaps most established. Most of this has been to do with the way in which schemes are evaluated. This has been echoed in the UK where official studies are recommending independent evaluation and auditing (Morton et al, 2005; Wilson, 2005).

Frameworks for such independent evaluation are emerging in Australia. Recently, a Personalised Travel Planning scheme in Victoria State was subjected to independent auditing using corroborative evidence (Stopher et al, 2005b). Results from traffic counters, public transport boardings and ticket sales all supported the results of the scheme. Analysis of bus boardings across a number of schemes in Australia, over an extended time period showed that the positive results are maintained in the medium to long term.

Similar results were found when public transport ridership figures were used to audit schemes in the UK. Overall, these schemes indicated mode transfer away from car usage, consistently, of 5 per cent - 10 per cent. Conservative estimates indicate that they support a benefit-cost ratio of at least 5:1. This is considered extremely favourable in transport

planning terms. Many infrastructural schemes are deemed of merit with benefit-cost ratios of 2:1 or less (Cohen, 2005).

One of the commendable aspects of the Personalised Travel Planning process, in fact, has been the emphasis placed on evaluation and this has probably been influential in the successful evangelisation of the concept. Such evaluation of travel behaviour is worthwhile in its own right. When deployed as part of a Personalised Travel Planning programme, it could just as easily form an integrated part of a wider transport strategy. In fact, strong arguments exist in favour of doing this.

4.2 Area Targeting Issues

Another issue within the Personalised Travel Planning debate is what areas it is likely to be successful in. This is pertinent, too, in deciding whether or not it would be a success in Dublin. Proponents of Personalised Travel Planning schemes are phlegmatic about this. They point to positive results from virtually anywhere that Personalised Travel Planning has been deployed. Also, they point to commonalities found across apparently contrasting travel markets. There are indications to suggest, however, that the Greater Dublin Area does offer some challenges to Personalised Travel Planning. Ireland has reportedly the highest average car-mileage in the world and much of this activity is attributable to the Greater Dublin Area (Bannister et al, 2000). Also, analysis of 2002 Census data shows vastly contrasting travel patterns even within otherwise broadly similar city-sectors.

Nevertheless, evidence suggests that Personalised Travel Planning can succeed within adverse environments. It should be noted that transport in Perth is predominantly car-based. The model of public transport provision in most Australian cities is market-based with commercial operators competing for business on high demand routes. This is not the optimum system for maximising boardings and accessibility (Mees, 2000; Casey, 2005). Perth is a dispersed low-density city with limited rail provisions. In other words, conditions for the promotion of public transport are not considered ideal yet significant results were achieved by Personalised Travel Planning schemes.

In Quedgeley, the area was specifically chosen for its high car ownership rate and available capacity on public transport (Sustrans, 2004a). However, no serious congestion was noted in the area prior to the study commencing. This indicates that there were no significant push factors in inducing mode transfer; yet tangible mode transfer did take place.

Walking is also the biggest benefactor in terms of mode transfer in almost every scheme (Department for Transport, 2004a; Brog, 2005). The evidence from the Sustainable Towns initiative where there was a clear relationship between distance to work and potential for change, suggests that areas where good land-use and transport planning has taken place are likely to display the biggest success rates (LTT, 2005a).

In the UK and Australia, however, higher success rates have been achieved in areas where demonstrable capacity existed on public transport routes. The Smarter Choices report was particularly effusive in suggesting that such schemes should be mixed in with harder measures, particularly service enhancements and demand management measures. Therefore, one recommendation would be to introduce Personalised Travel Planning schemes alongside new public transport initiatives.

4.3 Methodology Issues

The Smarter Choices report strongly points out that the projected changes in traffic levels and reduction in congestion, while large, are likely to attract more car use by other individuals (Department for Transport, 2004a). This would offset the benefit of the initial behaviour-change unless there are measures in place to prevent this. Therefore, the measured reallocation of road space to public and non-motorised modes can reinforce the initial programme and provide further inducements to switch modes among other users.

Of the various methodologies examined a number of features emerged as likely to be transferable to the Dublin market and contribute to successful mode transfer.

- Personalised Travel Planning Marketing Programme. A marketing programme that will assess the targets of the programme, the most appropriate means of delivering those targets and an accompanying but independent system of ongoing monitoring, feedback and improvement;
- Household surveys. The programme would rely on quality information derived from all individual households within the study area. Based on this information, fitting proposals can be devised to suit the needs of residents;
- Information tailoring and provision. The success of the scheme is based on the provision of tailored and relevant

information to each user. The preparation of travel packs with utilities such as localised bus timetables, walking information and other elements would need to be prepared as part of a programme;

- Incentivisation. As part of a marketing strategy, incentives can be organised, such as free bus passes and vouchers for cycle-stores, to promote increased use of public transport and non-motorised transport.
- Monitoring. In order to measure the success of the entire scheme as well as individual initiatives within the scheme, independently undertaken monitoring and evaluation against key performance indicators should be undertaken. The use of corroborative evidence appears to be highly valuable also;
- Formulation of individual initiatives. The overall programme will be a composite of several sub-initiatives, as deemed appropriate to the local area. These may include, among others, all or some of the following: Teleworking initiatives; School travel plans; Car-sharing / pooling initiatives; Cycle to work initiatives; Walk to PT initiatives; PT incentivisation schemes. Outreach programmes to related or compatible community organisations have also been successfully achieved in some Australian markets (Tideman, 2005).

An area that may need further analysis or piloting within the Greater Dublin Area is that of establishing contact methods. This is something that may naturally vary from market to market. While telephone contact is probably the quickest and cheapest mode of establishing initial contact and was very successful in many Australian pilots, it was less successful in some UK studies where door-to-door contact was reverted to (Socialdata, 2003a; Sustrans, 2004a). Door-to-door contact has been demonstrably successful in Adamstown but the question of transferability to much larger programs must be applied (South Dublin County Council, 2010).

Feedback processes have not been highlighted as part of previous Personalised Travel Planning studies. This is surprising given both the involvement of public transport agencies and also the high quality of information that can be assembled from a community relating to travel and mobility. It would seem an apparent waste of resources not to feed this information back into improved areas and services. A fundamental principle of marketing is product development and this is something that can take place within Personalised Travel Planning programmes.

4.4 Organisational Issues

A notable feature of all Personalised Travel Planning schemes is the involvement of a large number of entities. Personalised Travel Planning schemes are targeted at communities. Who these are and how they should be involved can best be identified by analysing who benefits from the concept.

Naturally the community themselves benefit and their involvement is tacit. Transport agencies benefit through increased ridership and a scheme is unlikely to have credibility without their involvement. The local authority is responsible for the area and any improvements to its character or amenity accrue to it. In new development areas, the developer may also benefit financially from increased marketing opportunities.

However, there are also significant environmental and health benefits that may occur as a result of the scheme. These can have a reductive impact on the budgets of both environmental departments and health departments. Safety authorities may also benefit through indirect expedition of their aims.

Experience indicates that environmental and health issues are effective marketing tools. Therefore, a strong argument exists for a partnership approach to coordinating Personalised Travel Planning initiatives. Such has successfully been the case in, for example, the UK where up to 10 logos have been published on literature and marketing collateral. In fact, the preparation and collation of such materials is a practical example of how such a partnership can work together to deliver the scheme.

Since the benefits of Personalised Travel Planning are dispersed, it is reasonable to suggest that so should be the costs. This is a consideration in raising the budget for schemes. For example, in the majority of Australian schemes, the budget comes not from transportation departments or local authorities, but from national and state greenhouse funds.

4.5 Conclusions

This study has examined the potential for Origin-based Mobility Management Plans, most specifically the newly emerging concept referred to as Personalised Travel Planning, in the Greater Dublin Area. The concept has been undoubtedly successful in other markets, as testified by

numerous independent and official sources. In addition, it has proved successful within areas demonstrating what may be described as adverse conditions for sustainable travel planning. Without the benefit of any direct applications within Ireland, it would appear to be an applicable methodology. Caveats from independent sources should be gleaned; some form of independent evaluation needs to be incorporated, for example. A high-level study in the UK, the Smarter Choices report, confirms the effectiveness of the scheme but concludes strongly that its real potential will only be realised when integrated into an overall transport strategy incorporating effective demand management measures.

4.6 Future Matters

The concept of Personalised Travel Planning is a relatively new one within transport planning. The overall area of behavioural-side policies can itself be identified as a new wave in the science of transport planning (Department for Transport, 2004a). Traditionally transport planning focussed on the delivery of infrastructure. Later, principles such as demand management and Land Use and Transportation Planning emerged (Buchanan, 1960). Behavioural-side planning is a new and relevant aspect to transport planning. Much of it is focussed on communicating with communities and as such it is very focussed on marketing. This in itself presents challenges to transport planners who are largely untrained in complex marketing concepts such as identifying "Stages of Change", for example (Davis, 2005).

Many analysts of Personalised Travel Planning complain of credibility issues when they quote benefit-cost ratios of anything between 5:1 up to 15:1, even though all the empirical evidence suggest that this is so (Cohen, 2005). It could be that this is a rational market response to the infinitesimally small resources that are applied to marketing alternatives to the car when compared with that invested in marketing the car.

The area of carbon-emissions trading is a matter that should be explored in relation to Personalised Travel Planning. Both seek to find market-based solutions to environmental problems. The potential for carbon emission reduction should not be lost on the proponents of Personalised Travel Planning and this could potentially provide a further revenue source to fund the scheme (Economist, 2002).

The main aim of Personalised Travel Planning must be, however, the reduction of car-based travel in favour of more sustainable options. A useful analogy to illustrate the potential effectiveness of the scheme is the potential for turning a vicious cycle into a virtuous cycle.

Increasing congestion can be described as a vicious cycle, whereby roads become clogged, public transport services deteriorate, forcing more travellers into the car, causing roads to become clogged, etc.

A virtuous cycle, on the other hand would show people opting for public transport, revenue for public transport, to be reinvested in better services, enticing more people onto public transport, etc.

To cause a transition from one cycle to another requires a three-stage process within a transport system: -

a) intervention
b) momentum
c) partnership approach

An intervention is required to halt the downward decline. A series of measures are required to give momentum to the upward cycle. A partnership approach between the responsible stakeholders is required to maintain momentum. A Personalised Travel Planning scheme can represent an intervention. However, it is unlikely to fulfil its full potential without measures to give it momentum and without a partnership approach to maintain the momentum.

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ESTIMATING THE POTENTIAL SUCCESS OF SUSTAINABLE TRANSPORT MEASURES FOR A SMALL TOWN

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ABSTRACT

This paper examines the benefits of promoting and encouraging the use of 'soft modes of transport' in a small town in Ireland. Currently in the town in question almost 70% of individuals drive to work alone each day. The Irish government has recently adopted a policy of actively promoting and developing sustainable towns through the use of soft transport measures. This paper takes a typical town in Ireland and demonstrates how a modal shift towards sustainable transport measures could result in a substantial saving in vehicle kilometres travelled and CO_2 emissions. Census data is used to estimate the benefits of a modal shift from driving alone to walking, cycling, and car-pooling. COPERT IV is used to estimate the reductions in CO_2 emissions if the modal shifts estimated were realised. An analysis of the commuting patterns of the individuals in the study area shows that the majority of car trips are less than 6km. The results of this study show that one soft measure promoted in isolation is not the 'silver bullet', but rather a mix of theses options would be optimal for achieving a modal shift.

Keywords: vehicle kilometres travelled, CO_2 emissions, soft modes, modal shift

1 INTRODUCTION

In Ireland, as in many other countries throughout the world, traffic levels are increasing. In 2008 private car ownership per 1,000 population increased by 0.6% (3.4% in 2007) resulting in an increase in car density to 435 cars per 1,000 population. This is compared to an EU-27 average of 464 and a UK average of 471 *(1)*. Over the period 2000 to 2008 the total mileage by all private cars increased by 38%, with the increase being 22% for petrol cars and 106% for diesel cars *(1)*.

Many factors have contributed to this situation, including increasing car ownership and numbers of drivers, reductions in car occupancy levels, changes in fuel price and varying levels of spending on roads. The cumulative effects of continually increasing traffic levels in urban areas are now causing serious economic, environmental, and social problems.

One of the most direct implications of the increase in road traffic is the effect on the environment. Concerns about the environmental impacts of road transport have grown. In many urban areas the private car is the single greatest polluter, predominantly due to the accumulation of vehicles on the road. In Ireland, emissions of carbon dioxide (CO_2) from fossil fuel combustion accounted for 68.6 % of total greenhouse gas emissions in 2007 compared to 58.5 % in 1990 *(2)*. Furthermore, between 1990 and 2007, Transport has shown the greatest increase at 178 %. Transport continues to be the dominant growth sector with emissions at 650,000 tonnes CO_2eq higher in 2007 than in 2006. In particular, road transport accounts for 97 % of the transport sector emissions *(2)*.

The general economic prosperity, increasing population, and consequent increasing vehicle numbers as well as the trend towards purchase of larger vehicles and the reliance on private cars, particularly in relation to commuting to and from work have been attributed as the main contributing factors for the increase in transport emissions over the last 17 years. In addition, another major factor has been the rapidly increasing road freight transport sector (i.e. light duty and heavy duty vehicles), with high construction activity also being a major influencing factor *(2)*.

With the forecasted growth in traffic, and the requirement for Ireland to meet its obligations under both the Kyoto protocol and under the EU 2020 binding targets, targeted local and national measures must be implemented which strive to reduce traffic and the environmental impacts rather

than measures that just restrain traffic growth. This is reiterated by Hickman and Banister *(3)* who argue that meeting national Kyoto reduction targets will require an integrated package of behavioural policy measures to ensure travel is conducted in a more carbon efficient way.

In February 2009 the Department of Transport launched "Smarter Travel – A Sustainable Transport Future", which sets out an action plan containing a target of getting 500,000 more people walking, cycling, using public transport and leaving their cars at home between now and 2020 *(4)*. With this action plan the Government aims to change the transport mix in Ireland so that by 2020 car use mode share for commuting reduces from the current level of 65% to 45%. In essence a range of policies and measures will be implemented that will facilitate progress towards integrating sustainability considerations into transport policy and, in particular, address the transport emissions issue.

Stemming from the Smarter Travel programme, in April 2009 the Department of Transport launched Ireland's First National Cycle Policy Framework *(5)*. In this new cycle policy document 109 individual but integrated actions are detailed, which will be taken over the coming 12 years to deliver a culture of safe cycling in Ireland by 2020. The Department envisions a strong cycling culture in Ireland, where all cities, towns, villages, and rural areas will be bicycle friendly. "*A culture of cycling will have developed in Ireland to the extent that 10% of all trips will be by bike by 2020*" *(5)*.

In 1986, 7% of all trips to work in Ireland were made by bicycle. However, by 1996 that figure had fallen to just over 4% and by 2006 commuter cycling had fallen to less than 2%. In 1986, 13% of all commute trips were on foot, by 2006 this had decreased to 11% *(6)*. If action is not taken to address these statistics car use will continue to increase and commuter walking and cycling modal share will continue to decline. Car ownership could increase to beyond EU average levels with the total number of private cars licensed possibly increasing from 1,800,000 to 2,470,000 *(4)*.

In July 2009 the Department of Transport launched a €50 million national competition aimed at funding and delivering innovative examples of sustainable travel in urban and rural areas right around the country. Smarter Travel Areas will provide an opportunity to demonstrate the benefits of sustainable transport, promoting and encouraging walking and cycling and reducing car travel, by improving travel facilities and promoting and encouraging behavioural change.

As walking and cycling are zero carbon activity, with no fuel requirements, they can be adopted as part of an overall strategy to reduce car travel and thus reduce CO_2 emissions and other green house gases. In 2004 the Department for Transport (UK) published a walking and cycling action plan, which, set out measures to increase levels of active travel across England *(7)*. Fifty case studies from that action plan have all shown significant improvements with often modest, but carefully selected initiatives. These schemes have improved local conditions for walking and cycling and encouraged people to walk and cycle, thus illustrating clear benefits in terms of reduced congestion, improved public health and enhanced quality of local streets and spaces *(8)*.

For example, Addenbrooke's Hospital in Eastern England invested in car sharing and pool cars, ran promotional events for bus travel, improved the walking and cycling infrastructure and worked with the main local bus operator on a Quality Bus Partnership. The impact of their workplace travel plan has been significant. For example, between 1993 and 2003 car use fell from 74% to 42%, bus travel rose from 4% to 23%, cycling went up from 17% to 25% and walking from 4% to 7% *(8)*.

The promotion of car-sharing in conjunction with other modes such as public transport is another approach advocated to reduce oil dependence problems *(9)*. Reductions in journey time and vehicle kilometres travelled (VKT), shared fuel costs, and decreases in emissions, may be achieved from encouraging ride-sharing *(10)*. Jacobson and King *(11)* examine the potential fuel savings in the US if policy of ride-sharing were promoted. It has been suggested that if 10% of cars were to have more than one passenger, it could result in a saving of 5.4% in annual fuel consumption. In 2005, the International Energy Agency examined the potential benefits of promoting ride-sharing, in Organisation for Economic Cooperation and Development (OECD) countries and found that by adding one person to every commute trip it would result in a saving of 7.7% on fuel consumption or 50,2223 barrels of oil a day and reduce VKTs by

12.5% *(12)*. Caulfield (13) found that car sharing in Dublin accounts for 4% of all trips to work and results in an annual VKT saving of 68million KMs. This paper does not address the potential mix of cycling / walking and other mobility management policies, e.g. measures to improve the walking cycling environment, improved facilities for walkers / cyclists or measures to influence travel behaviour, but rather focuses on the potential benefits should an optimal mix of policies be adopted.

2 METHODOLOGY

2.1 Data

The census data used in this paper was taken on the night of Sunday, 23rd April 2006 with 1.5 million Irish homes receiving the census forms two weeks before that. The data we use are taken from the place of work census of anonymised records dataset (POWCAR) *(14)*. The POWCAR dataset contains information on the regular work trips of 1,834,472 individuals in Ireland. Table 1 presents the structure of the data contained in the POWCAR dataset.

Unfortunately, income levels of respondents are not included in the dataset. Income is an important factor when analysing individuals travel behaviour. The objective of this paper is to examine the impact of softer measures adopted in a small town. A small town with a population of just over 25,000 inhabitants was chosen as the study area. Over 7,500 individuals commute into the study area each day to work.

2.2 Model Formulation

The model estimated in this paper examines the characteristics of the individuals that drive to work in the study area. A number of activity variables are examined in the first set of models such as, travel time and distance and departure time. A multinomial logistic regression analysis was constructed to analyse the relationship between these factors and those that indicated that they drove to work on a regular basis. The model takes the following functional form:

$$\text{logit}(p) = \log\frac{p}{1-p} \equiv \alpha + \beta I + \gamma H + e \qquad (1)$$

Where p is the probability that event Y occurs (driving to work), βI is the set of individual specific characteristics, γH is the set of household specific characteristics, and e is a random error term. Table 1 details each of the variables estimated in the regression model. All of the variables detailed in Table 1 are dummy variables. COPERT IV is used in this paper to estimate the reduction in emissions. The details of the private fleet of vehicles used for estimating savings in CO^2 emissions were taken from the government vehicle registration records *(15)*. Monthly average temperatures for 2006 were also inputted into the model.

Table 1. Details of Variables Examined

Variable	Definition
Distance	
Distance: 0-5 km	= 1 if Distance: 0-5 km
Distance: 6-10 km	= 1 if Distance: 6-10 km
Distance: 11-15 km	= 1 if Distance: 11-15 km
Distance: 16-20 km	= 1 if Distance: 16-20 km
Distance: 21-30 km	= 1 if Distance: 21-30 km
Distance: 31 -40 km	= 1 if Distance: 31 -40 km
Distance: 41 + km	(Reference category = Distance: 41 + km)
Travel Time	
Travel time: 0-5 mins	= 1 if Travel time: 0-5 mins
Travel time: 6-10 mins	= 1 if Travel time: 6-10 mins
Travel time: 11-20 mins	= 1 if Travel time: 11-20 mins
Travel time: 21-30mins	= 1 if Travel time: 21-30mins
Travel time: 31-40 mins	= 1 if Travel time: 31-40 mins
Travel time: 41-50 mins	= 1 if Travel time: 41-50 mins
Travel time: 51 + mins	(Reference category = Travel time: 51 + mins)
Age	
Age: 15-24	= 1 if Age: 15-24
Age: 25-34	= 1 if Age: 25-34
Age: 35-44	= 1 if Age: 35-44
Age: 45-54	= 1 if Age: 45-54
Age: 55-64	= 1 if Age: 55-64
Age: 65-74	= 1 if Age: 65-74
Age: 75+	(Reference category = Age: 75+)

Variable	Definition
Gender	
Gender: Male	= 1 if Gender: male
Gender: Female	(Reference category = Gender: Female)
Socio-economic group	
Socio-economic group: Employers and managers	= 1 if Socio-economic group: Employers and managers
Socio-economic group: Higher professional	= 1 if Socio-economic group: Higher professional
Socio-economic group: Lower professional	= 1 if Socio-economic group: Lower professional
Socio-economic group: Non-manual	= 1 if Socio-economic group: Non-manual
Socio-economic group: Manual skilled	= 1 if Socio-economic group: Manual skilled
Socio-economic group: Semi skilled	= 1 if Socio-economic group: Semi skilled
Socio-economic group: Unskilled	= 1 if Socio-economic group: Unskilled
Socio-economic group: Self employed	= 1 if Socio-economic group: Self employed
Socio-economic group: Farmers	= 1 if Socio-economic group: Farmers
Socio-economic group: Agricultural workers	= 1 if Socio-economic group: Agricultural workers
Socio-economic group: Other	(Reference category = Socio-economic group: Other)

3 RESULTS

This section of the paper presents the results of the analysis conducted to measure the benefits of promoting a number of soft measures in the study area. The results examine the benefits of these soft measures in terms of vehicle km saved and annual CO_2 emissions saved. This section of the paper also examines the individuals most likely to drive to work in the study area.

3.1 Details of the Study Area

The first set of results detailed in Table 2 report the modal split of the study area, and the national modal split. The mean distance travelled and travel times are also reported in Table 2. The results show that the majority of individuals in the study area (68.8%) travel by car to work. The modal share of car is 10% higher than the national average in the study area. The modal share shows that a high percentage of individuals in the study area walk to work on a regular basis. One other result of interest is that 2.9% of individuals in the study area use public transport to travel to work, this is substantially less than the 9% national figure.

Table 2. Modal Split of Morning Commuters into Study Town

Study Area								
Mode	N	%	Mean distance in km	Standard Deviation distance in km	Mode distance in km	Mean Travel time in mins	Standard Deviation time in mins	Mode time in mins
Walk	1,105	14.7	1.76	1	1	14	10	9
Cycle	88	1.2	2.49	1.6	2	12	6	10
Public transport	219	2.9	19.52	15	15	34	27	20
Motorcycle	25	0.3	10.95	10.3	2	16	11	10
Driving	5,181	68.8	15.92	14.9	2	23	17	10
Driving – Passenger	514	6.7	10.67	12.6	3	18	14.3	10
Lorry or van	305	4.0	17.06	15.4	2	26	23.7	15
Other means	12	0.2	-	-	-	-	-	-
Work from home	38	0.5	-	-	-	-	-	-
NA	49	0.7	-	-	-	-	-	-
Total	7,536	100.0	-	-	-	-	-	-
National								
Walk	197,622	10.9	1.82	1.37	1	15	12	10
Cycle	35,310	1.9	4.83	3.84	2	14	12	10
Public transport	164,066	9.0	12.18	15	10	42	27	60
Motorcycle	12,678	0.7	13.32	12.70	10	24	17	20
Driving	1,052,795	58.1	16.36	16.50	10	27	23	10
Driving – Passenger	102,483	5.7	13.40	14.82	10	23	20	10
Lorry or van	138,208	7.6	21.36	19.88	10	33	29	30
Other means	6,228	0.3	-	-	-	-	-	-
Work from home	56,897	3.1	-	-	-	-	-	-
NA	45,634	2.5	-	-	-	-	-	-
Total	1,811,921	100.0	-	-	-	-	-	-

3.2 Examining the Characterises of Individuals that Drive to Work in the Study Area

This section of the paper examines the characteristics of the individuals that drive to work in the study area. Table 3 details the results of a logistic regression analysis used to measure the characteristics of the individuals that drive to work. The first characteristic examined in Table 3 relates to the distance travelled by those that drive to work. The results show that those that drive to work in the study area are more likely to drive less than 10km (see Table 3). The results also show that those that drive to work are more likely to have short commuting times of less than 10 minutes. These findings suggest that motorists are more likely to have shorter commuting distances and travel times than those that use alternative modes of transport.

Table 3 Regression Analysis Results

		Estimate	p-value
Intercept		.016	.005
Distance:	0-5 km	3.374	.000
	6-10 km	1.150	.000
	11-15 km	.941	.000
	16-20 km	.535	.001
	21-30 km	.583	.000
	31 -40 km	.638	.000
	41 + km	0(b)	.
Travel Time	0-5 mins	2.268	.000
	6-10 mins	2.359	.000
	11-20 mins	1.372	.001
	21-30mins	.960	.000
	31-40 mins	.947	.000
	41-50 mins	1.093	.000
	51 + mins	0(b)	.
Departure Time	Before 06:30	-.415	.001
	06:31-07:00	-.349	.001
	07:01-07:30	-.040	.000
	07:31- 08:00	.253	.000
	08:01- 08:30	.068	.000
	08:31 – 09:00	.635	.000
	09:01-09:30	-.680	.000
	After – 09:30	-.649	.000
	NA	0(b)	.
Age	15-24	-.264	.000
	25-34	.857	.000
	35-44	.996	.001
	45-54	1.088	.001
	55-64	1.196	.000
	65-74	1.977	.000
	75+	0(b)	.
Gender	Male	-.452	.000
	Female	0(b)	.
Socio-Economic Group	Employers and managers	1.280	.000
	Higher professional	1.690	.000
	Lower professional	1.645	.000
	Non-manual	.808	.000
	Manual skilled	.170	.000
	Semi skilled	.690	.000
	Unskilled	.172	.000
	Self employed	.620	.000
	Farmers	.809	.000
	Agricultural workers	.058	.000
	Other	0(b)	.
- 2 log-likelihood at convergence		3574.39	
N		5,181	
R2		.319	

The results for the departure time show that positive coefficients were estimated for those individuals that departed between 7:00 am and 9:00am. This result suggests that those individuals that drive to work are most likely to depart for work during this time period. The age profile of individuals that drive to work on a regular basis is also examined in Table 3. The findings suggest that individuals aged between 15 and 24 are unlikely to drive to work, whilst individuals in the older age groups were more likely to drive to work.

The gender coefficient estimated in Table 3 demonstrates that females are more likely to drive to work. This could be due to other non-work commitments such as dropping children to school and therefore would require a car for this trip. Information on such trips is not included in the dataset examined. The final set of variables examined in Table 3 measure how an individuals socio-economic group in likely to have an impact upon driving to work. Each of the occupation variables estimated were found to be positive. The results show that 'employers and managers', 'higher professionals' and 'lower professionals' were most likely to drive to work compared to the other groupings. The results presented in Table 3 demonstrate that the individuals that drive to work in the study are most likely to have shorter

commuting distances and travel times. It is the individuals that make these trips that are targeted to move to more sustainable modes of transport in the following sections. It is this group of individuals who are investigated further in the following sections as their short distance may make them ideal candidates for switching to other modes of travel to work.

3.3 Distances Driven by Individuals to Work in the Study Area

Table 4 examines the distances travelled by individuals who drive to work. The distances driven to work are segmented into three categories: individuals that travel less than 2km to work; 2-6km to work and more than 6km. Fourteen percent of individuals that drive to work travel less than 2km and 21% of individuals drive between 2 and 6km to get to work. In the subsequent analysis individuals that drive less than 2km will be targeted to walk to work and those that travel between 2 and 6km will be targeted to cycle to work.

Table 4. Distances Travelled by Individuals Driving Alone to Work

Distance	N	%
Less than 2 km	655	14
2-6km	1,012	21
More than 6 km	3,081	65
Total	4,748	100

3.4 Examining the Benefits of a Modal Shift from Driving Alone to Walking to Work

This section of the paper examines the benefits of a modal shift from driving alone to walking to work on a regular basis. The environmental benefits of a modal shift to walking to work were estimated using COPERT IV. The scenarios examined in Table 5 assume that a percentage of individuals that currently drive less than 2 km to work each day start to walk to work. The six scenarios examined estimate the impact varying percentages of individuals switching from driving alone to work to walking 5, 4 or 3 days a week. The results in Table 4 show that 14% (655) of individuals drive less than 2km to work each day. The first set of scenarios examine the impact on VKT and CO_2 emissions save if 5% of individuals that currently drive less than 2km walked to work either 5, 4 or 3 days a week. The results in Table 5 show that modest annual CO_2 emissions savings would occur if a 5% modal shift towards walking were to occur. Further more a substantial annual vehicle km travelled saved could be realised if a modal shift towards walking occurred.

The second set of scenarios examined in Table 5 measure the impact of a 10% modal shift from driving alone to walking to work. The results show, as one would expect, that a greater annual CO_2 emissions saving would be realised with a 10% modal shift, as well as greater savings in VKT.

Table 5. Potential Benefits for a Modal Shift from Drive Alone to Walking

% Modal Shift/No. Days per Week	VKT (annual savings)	CO_2 Emissions Saved (annual savings)
5% modal shift to walking – 5 days a week	23,914 km	4.44 (tonnes)
5% modal shift to walking – 4 days a week	15,870 km	2.95 (tonnes)
5% modal shift to walking – 3 days a week	14,348 km	2.67 (tonnes)
10% modal shift to walking – 5 days a week	47,828 km	8.89 (tonnes)
10% modal shift to walking – 4 days a week	31,740 km	5.90 (tonnes)
10% modal shift to walking – 3 days a week	28,969 km	5.38 (tonnes)

3.5 Examining the Benefits of a Modal Shift from Driving Alone to Cycling to Work

The benefits of a modal shift to cycling to work from driving alone are presented in Table 6. The scenarios examined in this section of the paper are similar to those in the previous section, in that they examine the environmental benefits of a modal shift to cycling from drive alone. The group of individuals examined are those that drive 2 to 6km to work each day. The results in Table 4 show that 21% (1,012) individuals drive 2 to 6km to work on a regular basis. The COPERT IV model was used to

estimate the environmental benefits in terms of an annual reduction in CO_2 emissions.

The results show that if a 5% modal shift to cycling to work were realised, for even part of the week, a substantial annual saving in vehicle km travelled and CO_2 emissions could be achieved. The results for a 10% modal shift from driving alone to cycling were found to result in an increased saving in km travelled and CO_2 emissions.

Table 6. Potential Benefits of a Modal shift from Drive Alone to Cycling

% Modal Shift/No. Days per Week	**VKT (annual savings)**	**CO_2 Emissions Saved (annual savings)**
5% modal shift to cycling – 5 days a week	93,192 km	17.32 tonnes
5% modal shift to cycling – 4 days a week	61,845 km	11.49 tonnes
5% modal shift to cycling – 3 days a week	55,915 km	10.39 tonnes
10% modal shift to cycling – 5 days a week	186,384 km	34.64 tonnes
10% modal shift to cycling – 4 days a week	123,691 km	22.99 tonnes
10% modal shift to cycling – 3 days a week	111,830 km	20.78 tonnes

3.6 Examining the Benefits of a Modal Shift from Driving Alone to Car-Pooling

The final soft measure examined in this paper measures the potential for car-pooling in the study area. The data used in this study is segmented by districts. Each of the electoral districts that individuals in the study are travel from to work were examined. The three districts with the highest concentrations of individuals driving alone to work in the town centre were examined to ascertain the potential for car-pooling. The departure times of the individuals in these three areas are examined and presented in Table 7. The results show that in each of the areas examined there is potential for individuals to car-pool. As the individuals in these areas have the same origin, destination and departure time it is fair to say that there is potential for these individuals to car-pool. The results in Table 8 detail the benefits of a percentage of the individuals switching from driving alone to car-pooling.

Table 7. Identifying Individuals Most Capable of Car-Pooling

Departure Time	**Area 1**		**Area 2**		**Area 3**	
	N	**%**	**N**	**%**	**N**	**%**
Before 06:30	28	2	6	3	2	1
06:31-07:00	56	3	7	4	4	2
07:01-07:30	82	5	6	3	17	11
07:31-08:00	189	12	24	13	27	17
08:01-08:30	337	21	34	18	51	32
08:31-09:00	493	30	63	34	37	23
09:01-09:30	229	14	29	16	12	7
After 09:30	164	10	16	9	10	6
NA	61	4	2	1	1	1
Total	1639	100	187	100	161	100

The results in Table 8 examine the potential benefits of a modal shift from driving alone to car-pooling. As with the previous scenarios for modal shifts to walking and cycling, the results in Table 8 examine the benefits of a 5% or 10% modal shift to car-pooling on either 5,4 or 3 days a week. The results from each of the scenarios show that a considerable reduction in annual vehicle km travelled and annual CO_2 emissions saved can be achieved under such a measure.

Table 8. Potential Benefits for a Modal Shift from Drive Alone to Ride-Share

% Modal Shift/No. Days per Week	**VKT (annual savings)**	**CO_2 Emissions Saved (annual savings)**
5% modal shift to ride-share – 5 days a week	80,395 km	14.94 tonnes
5% modal shift to ride-share – 4 days a week	64,316 km	11.95 tonnes
5% modal shift to ride-share – 3 days a week	48,237 km	8.96 tonnes
10% modal shift to ride-share – 5 days a week	161,275 km	29.97 tonnes
10% modal shift to ride-share – 4 days a week	129,020 km	23.98 tonnes
10% modal shift to ride-share – 3 days a week	96,765 km	17.89 tonnes

4 DISCUSSION AND CONCLUSIONS

The results presented in this paper demonstrate that due to the low commuting distances associated with small towns, they can be an ideal candidate for sustainable transport options. Low cost options such as those examined in this paper are suited to smaller towns where the financial resources to operate or construct traditional transport alternatives may not exist.

The findings of this study show that a combination of soft measures can result in substantial environmental benefits. The potential for modal shift for individuals that are within walking and cycling distances to the town centre has been examined. The individuals that are assumed to car-pool reside in areas where there is significant potential to find a car-pooling partner. The results of the scenarios estimated in this paper show that if a modal shift were to occur it would result in a substantial saving in emissions and vehicle kilometres travelled.

Based upon the findings of this paper it is clear that no one soft measure would result in a substantial change in transport emissions or vehicle km travelled. If a combination of walking, cycling and car pooling were examined in this paper were adopted in the study area, it would result in considerable benefits to the environment.

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Unsustainable commuting patterns - the legacy of the housing boom in Dublin

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ABSTRACT

With the end of the recent unprecedented housing boom in Dublin, Ireland, it is perhaps a good time to analyse how the commuting and development patterns have been impacted by the unprecedented level of housing construction in recent years. In this research, we focus specifically on the commuting patterns of those individuals living in the newest housing stock to see how these patterns to see if they adhere to the Irish government's stated transportation and sustainability goals. Data from the 2006 Census of Ireland is used to explore the commuting patterns of individuals living in the four counties that make up Dublin who lived in the most recently constructed housing stock (built between 2001 and 2006, constituting almost one fifth of all housing units in Dublin). A number on logistic regression models were estimated to compare commuting patterns of individuals living in the older housing stock to individuals living in housing built during the property boom. The results demonstrate that the latter population were more likely to have longer commute times and to depart earlier to get to work. The findings also suggest that, despite ambitious government level goals, housing built during the property boom was more likely to be in low density areas.

1 INTRODUCTION

After almost fifteen years of unprecedented economic growth, the Irish economy is now experiencing one of the largest declines experienced by any developed country since World War II (ESRI, 2009). After an export-led boom that was fuelled by large increases in productivity per capita in the last years of the 20th century and the first years of this, recent economic growth has been largely driven by the construction of housing units. Ireland experienced perhaps the largest expansion in housing supply of any economy in Europe. The number of units built annually peaked at 88,000 in 2007 which translated to 18 units per 1,000 people, more than three times the average rate for eighteen other European countries measured (CSO, 2008a). In tandem with this, house prices increased by 65% and the amount of total mortgage debt almost trebled to EUR140B between 2002 and 2007, reflecting an increased demand and a doubling in the average loan for new mortgage holders (CSO, 2008b).

In that period, Dublin, as capital of Ireland, was an economic driver and the area, like the rest of the country underwent significant economic and demographic changes with increases in employment, income, and residents. Already a low density city by European standards (Commins and Nolan, 2008), rapidly increasing house prices (along with other pressures such as road congestion and demand for oversubscribed services) incentivised developers and potential buyers to locate further from the traditional Central Business District (CBD) (Vega and Reynolds-Feighan, 2008). These pressures led to rapid development activity and population increases beyond the traditional boundaries of the city and are changing the relatively monocentic nature of the City (Vega and Reynolds-Feighan, (2008) and Convery et al (2006)). Consequently, the population of the Greater Dublin Area (GDA), an area defined as the four counties of Dublin and the three adjacent counties, increased by 20% between 1996 and 2006 while the numbers in employment increased by almost a half with the largest increases occurring outside Dublin City (Commins and Nolan, 2008).

In tandem with the increases and dispersion in economic and settlement activity, transportation patterns also changed significantly. Firstly, the oft-reported relationship between economic growth and increased car ownership was particularly pronounced in Ireland (Dargay, (2001) and Dargay and Gately (1999)). In the Irish context this was particularly magnified given the increased suburbanisation of non-traditional "commuter areas". While the car ownership level remains slightly below the European average, the number of registered private cars has almost doubled since 1996, standing at 1.9 million cars in 2007, of which the GDA accounted for some 720,000 cars (CSO, 2008b). This increase in car ownership was also

reflected in a larger share of GDA commuter trips (which we define as trip to work, school or college) undertaken using cars, increasing from under 47% to almost 52% in the 10 years to 2006 (Commins and Nolan, 2008). The combination of increasing economic and transport activity, dependence on car travel and the diffusion of settlement patterns are all closely interrelated. Other researchers have found that mode choice and transit usage are impacted primarily by density and land use (Ewing and Cervero, 2001); both variables are largely defined by policy decisions in Ireland (e.g. through zoning). Distance from the central business district is also an important determinant of mode choice (Puskarev and Zupan, (1977) and Johnson (2003)). Similar to other economies, these interrelationships have resulted in worsening congestion and environmental performance as the private cost of motoring is often less than the costs imposed on society, especially in urban areas (Sterner, 2003). Not only have travel speeds decreased for road commuters, with the possible exception of the City's network of Quality Bus Corridors (Caulfield and O'Mahony (2004) and McDonnell et al (2008)), carbon dioxide (CO_2) emissions from transport have increased significantly in Ireland over the boom period (McDonnell et al, 2008).

With the City and the country undergoing a significant economic reversal, it is perhaps an appropriate time for researchers to conduct an overview of the boom's impacts on transportation patterns for the Dublin area. As Scott (2004) notes when questioning if longer journey times were the result of current government policy, planning laws need regular assessment in terms of their effects. In this research we focus on the residents living in the four counties that make up Dublin. Data from the 2006 census is used to analyse how transport patterns of differ based upon some key housing and land use characteristics, such as the number of public transportation options available, density and the year of housing construction. With this last variable, we want to explore how commuting patterns differ, if at all, as a result of the housing age, holding all else equal, from those living in housing units constructed in earlier periods.

The paper is outlined as follows: in the next section we briefly review the policy context for our research question by outlining some of the stated transportation and sustainability goals of the Irish government and review the relevant academic literature. The following section outlines our methodological approach for answering our research question. The results of the research are presented in the last section of the paper. The paper concludes with an overview of the results and a policy discussion.

2 POLICY CONTEXT AND LITRATURE REVIEW

The Irish government have outlined a number of very ambitious strategies in the transportation and sustainability realms for both the medium and long term. In the transport sphere, response has generally taken two forms – infrastructural (increased road capacity by widening and expanding the road network, provision of additional heavy rail capacity, light rail, bus priority etc.) and demand side management aimed at tackling congestion (parking pricing, transportation allowances, transit and rideshare financial incentives, public transport pass programmes etc.). Despite interest from many researchers about congestion charging, there remains little appetite for first or second-best policy instruments approximating the marginal external costs of private transport in advance of the provision of a large scale investment in a mass transit alternative. This was meant to be achieved through the implementation of a number of National Development Plans (NDP) and various strategic transport plans (see for instance: Barrett et al (1979), DTI (1995), DTO (2000) and DTO (2002)). The latest plan, a massive infrastructural investment program entitled Transport 21 (DOT, 2005) outlined an investment of almost EUR35 billion in transport infrastructure nationally, about 50% going to public transportation. However, the delivery of these plans have been characterised by administrative, regulatory and financing holdups (McDonnell, 2008). The latter of which is likely to be the primary constraint as the finances of the Irish government worsen (DOF, 2009). In the interim, as we have noted, the car has gained an increased share of peak time travel market. A key concern is the environmental sphere has been to maintain or even reverse this trend. This latter point is especially important given that, as of 2005, Ireland was emitting 25% more CO2 than in 1990 levels, 12 percentage points more than it is permitted under is Kyoto commitments (EPA (2005) and Duffy (2009)). A number of strategies have been developed by the government to better integrate transportation and land use polices (see for instance: DOE (1997) and DELG (2002)), but the diffuse nature of decision making in Dublin has

hindered integrated land use planning (DELG (2001) and Redmond (2007)); the City and County of Dublin, with a population of 1.2 million people is divided into four jurisdictions, each with their own planning powers. The most recent intervention (DOT, 2008) again stresses the need to align spatial and transport planning to improve environmental outcomes; for a broader historical overview of the policy context (Ellis, 2001).

The interaction between land use and transportation is an extremely well explored topic (Button et al 2005). Ewing and Cervero (2001) conducted meta-analyses of the relationships between the built environment and travel characteristics in 2001 and, again, in 2010 (Ewing and Cervero (2001 and 2010). The earlier analysis highlights the importance of density and land use; trip lengths are also a function of the built environment. In contrast, trip frequencies are more closely related to socio-economic characteristics. Higher densities are generally associated with wider selections of accessible mixed use destinations and more sustainable transportation patterns (USEPA, 2006). Density is also correlated with lower car ownership; research in the United States has found that, with each doubling of residential density, car ownership declines by 32-40% (Holtzclaw et al 2002). Other researchers find that the distance from downtown is also important in determining transportation usage (Puskarev and Zupan (1977), Johnson (2003)).

Ewing and Cervero's more recent analysis reinforces much of their earlier research (Ewing and Cervero, 2010). Distances travelled are most strongly related to destination accessibility while bus and train use are related to transit proximity, land use diversity also having and influence. Walking is related to density and land use diversity. They also highlight residential neighbourhood "self-selection" identification problems in the literature; however, of nearly all studies exploring this issue have found statistically significant association between the built environment and travel patterns, controlling for self-selection. Much research in the area of land use and transportation has focused on the concept transit-oriented development (TOD) (e.g., Cervero et al (2010), Gomez- Ibanez et al (2009)).

The continued disconnect between land use and transportation planning in the Dublin area has also spurned considerable interest amongst researchers in Ireland. Williams and Shiels (Williams and Shiels, 2002) characterise the development patterns in the greater Dublin as laissez faire, without any real inter-linkage between county-level planning, where land use policies are largely determined, and the strategies of the Dublin Transportation Office (DTO), the body charged with outlining a transport vision for the greater Dublin area. Williams et al. (2002) define these patterns as unsustainable; Duffy (2009) finds that CO2 lifecycle emissions are over 50% higher in GDA exurbs and commuter towns than in the CBD. Both Williams and Shiels (2002) and Williams et al. (2002) offer detailed qualitative narratives of development in the GDA. Vega and Reynolds-Feighan (2008), in a quantitative analysis, use data from the 2002 census to identify employment sub-centres in the Dublin region and how their spatial distribution affects travel choices. They find that, despite the presence of sub-centres, the CBD still accounts for a much higher proportion of regional jobs than comparable cities in the United States. This continued "centeredness" Ewing et al (2002) seems to indicate that the move away from monocentricity, identified by Murphy (2004) and Convery et al. (2006), is less pronounced in Dublin. Using a binomial logit structure, they also model travel choice between private car and a general public transport alternative (ignoring non-motorised modes). They find that commuters generally show low sensitivity to changes in car travel times but are more sensitive to changes in public transport travel times, possibly indicating a reluctance amongst car users to switch modes (McDonnell et al (2009). Public transport users are also more sensitive to travel cost changes. The authors conclude that these differences will undermine travel demand management policies in the absence of more comprehensive public transportation infrastructure. However, the analysis, which is restricted to a sample of the 2002 census, does not model the influence of residential location, housing type or age on modal choice. Nor does it differentiate between different forms of public transport or accessibility to public transportation facilities.

In contrast, Commins and Nolan (2008) include housing type in their analysis of the determinants of modal choice. They are also able to employ data from the 2006 census which, for the first time, includes microdata on all working individuals over the age of 15, something that our research also exploits. Taking a 10% sample of the data, the authors use a conditional logit model to estimate choice probabilities for seven transport mode alternatives for the sample using individual-level

and alternative-specific explanatory variables (an alternative model with three aggregated alternatives is also developed). The authors find that, in line with many other studies, older residents (compared to those in the 15-24 age group), those with car availability and those with higher socio-economic status are less likely to use public or non-motorised transport. Those working in the CBD, on the other hand are significantly more likely to be public or non-motorised transport users. While the authors highlight out the importance of housing type in modal choice, the age of the housing units is not included in the specification and public transportation accessibility is not measured.

3. METHODOLOGY

3.1 Data

The census data used in this paper was taken on the night of Sunday, 23rd April 2006 in 1.5 million Irish homes. Our data are taken from the place of work census of anonymised records dataset (POWCAR) (CSO, 2007). It contains information on the regular work trips of 1,834,472 individuals. Unfortunately, income levels of respondents, an important determinant of travel behaviour, are not included in the dataset.

3.2 Model formulation

Three mode choice models are estimated in this paper. The purpose of these models is to ascertain how the modal choice of residents in Dublin relates to a number of housing and transportation characteristics. The variables include the number of cars per household and the level of housing density, the number of bus stops in the respondent's vicinity and if a rail station is within the resident's vicinity (both of which we define as an electoral district, the smallest level of geography available to us). A number of activity variables are also examined such as, travel time and distance and departure time. Binary logistic regression analysis was constructed for each model to analyse the relationship between these factors and the year in which the individuals' modal choice (walking versus other mode; public transportation versus other mode or car driver versus other mode). The model takes the following functional form:

$$\text{logit (p)} = \log\frac{p}{1-p} \equiv a + \beta I + \gamma H + e \qquad (1)$$

Where p is the probability that event Y occurs (year house was built), βI is the set of transportation specific characteristics, γH is the set of household specific characteristics, and e is a random error term.

4. RESULTS

This section of the paper reports the results of the analysis conducted on the 2006 Census dataset. The first section provides a descriptive overview of the increases in the number of houses built in Dublin and the modes of transport used to travel to work. The results of the multinomial logistic regression analysis are also presented in this section.

4.1 Characteristics of the sample

The top portion of Table 1 details the number of houses built in Dublin from 1919 to 2006. As already discussed, recent growth in the Irish economy was largely fuelled by growth in the housing stock. This is especially evident when one considers the results presented in Table 1. In fact, between 2001 and 2006, over 15% of the total housing stock in the Dublin was built and almost 25% of the housing stock was built within a decade of the last census. The annual construction rate of over 15,000 housing units in the last five year period.

The bottom portion of Table 1 details the modes of transport used by residents in Dublin. The results show that the majority of individuals drive to work (49%). Interestingly, a sizable proportion of individuals walk to work (13%). Public transport accounts for 21% of daily work trips in Dublin, the bus accounting for two thirds of that.

TABLE 1 Number of houses built and mode of transport

Year Built				
	N	**%**	**Number of houses built per annum**	
1919 - 1970	182,786	36	3,584	
1971-1995	196,603	39	8,192	
1996-2000	49,102	10	12,276	
2001-2006	76,828	15	15,366	
Total	505,319	100		
Mode of Transport				
	N	**%**	**Average distance (KM)**	**Average travel time (minutes)**
Walk	70,080	13	2.17	19
Cycle	20,602	4	5.48	22
Bus	76,816	14	9.51	43
Rail	39,534	7	13.47	45
Motorcycle	6,607	1	10.84	25
Car – Driver	260,754	49	11.24	31
Car – Passenger	19,997	4	9.75	28
Lorry/Van	19,239	4	13.91	35
Other means	1,028	0	-	-
Work from home	8,218	2	-	-
NA	9,354	2	-	-
Total	532,219	100	-	-

4.2 Characteristics of the housing location

We conducted a cross-tabulation analysis to develop a clearer picture of the housing stock with respect to a number of factors related to sustainability and liveability (see Table 2). We examine public transport availability, residential density and the number of cars per-household in relation to the year of housing construction. The first set of results relate to the number of bus stops available. Our measure represents the average number of bus stops available per-person in each of the housing categories examined. We see that the number of bus stops in each of the housing categories increase from 5.35 for those houses built before 1919 to 8.11 for those built in 2001-2006. One interesting result to note is the 5% increase in housing units with no access to a bus stop between 1996-00 and 2001-06. The results for rail availability shows that housing stock built before 1940 had greater access to rail, this then decreases until the housing stock built in 1991-95 where there is slight increase. A limited radial rail network exists in Dublin and the bus network is the work horse of the public transport network; therefore it is not surprising to see only 20-30% of the population of the city with access to a rail station.

The next set of results examines the impact of residential density. Our measure represents the average density for the housing in each of the categories examined and show that the average density decreases for newer housing. The results show a 16% increase in housing units built in the lowest density category between 1996-00 and 2001-06. This result demonstrates that during this period that the housing constructed was predominantly in low density areas. The final set of results presented in Table 2 examines the rates of car ownership. The highest levels of car ownership were shown to be in households living in housing stock built in the period 1961-95. Interestingly average car ownership levels were shown to drop from 1.54, for those living in housing built in 1996-00, to 1.40 for those living in housing built in 2001-06. This perhaps reflects an income effect which we are unable to capture with our data.

TABLE 2 Cross tabulation between housing stock and location characteristics.

Year built	Before 1919		1919-40		1941-60		1961-70		1971-80		1981-90		1991-95		1996-00		2001-06	
No. of bus stops	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
None	9,655	24	9,463	28	18,372	31	12,754	26	21,020	22	12,224	19	6,587	17	8,459	17	17,267	22
1-5 stops	16,189	41	15,347	45	25,840	44	18,471	37	34,559	37	20,927	33	11,047	28	13,263	27	19,104	25
6-10 stops	8,286	21	6,555	19	11,413	19	12,919	26	24,043	25	16,168	26	9,921	25	9,232	19	20,005	26
11-20 stops	4,314	11	1,898	6	3,250	5	4,764	10	7,830	8	6,864	11	5,480	14	4,719	10	7,965	10
20+ stops	1,353	3	514	2	457	1	972	2	6,960	7	6,702	11	6,271	16	13,429	27	12,487	16
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62,885	100	39,306	100	49,102	100	76,828	100
Average		5.35		4.17		4.0		5.16		6.01		7.19		8.56		9.6		8.11
Rail available																		
No	27,762	70	25,521	76	49,454	83	42,101	84	77,555	82	50,194	80	29,802	76	38,929	79	61,634	80
Yes	12,035	30	8,256	24	9,878	17	7,779	16	16,857	18	12,691	20	9,504	24	10,173	21	15,194	20
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62,885	100	39,306	100	49,102	100	76,828	100
Density																		
Less than 1000 per km^2	2,140	5	1,361	4	1,674	3	3,475	7	9,145	10	7,018	11	4,680	12	7,001	14	23,094	30
1001-3000 per km^2	5,064	13	5,830	17	11,812	20	12,139	24	29,761	32	25,233	40	11,783	30	10,701	22	17,265	22
3001-6000 per km^2	11,908	30	13,263	39	32,459	55	27,284	55	48,216	51	24,518	39	16,295	41	24,797	51	26,932	35
6001 - 9000 per km^2	11,552	29	10,191	30	10,850	18	5,928	12	6,397	7	4,630	7	3,947	10	3,963	8	6,151	8
9001 – 12000 per km^2	7,524	19	2,397	7	2,059	3	855	2	632	1	1,079	2	1,605	4	1,267	3	2,342	3
12001 + per km^2	1,609	4	735	2	478	1	199	0	261	0	407	1	996	3	1,373	3	1,044	1
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62,885	100	39,306	100	49,102	100	76,828	100
Average		6,356		5,444		4,722		4109		3,593		3,435		4,060		4,047		3,288
Number of cars																		
One	14,462	37	12,879	39	22,526	38	16,463	33	30,128	32	22,480	36	13,241	34	16,495	34	31,380	41
Two	11,397	29	11,211	34	20,897	36	19,966	40	37,627	40	24,399	39	16,335	42	20,754	43	28,519	38
Three or more	3,741	10	3,424	10	6,587	11	7,621	15	18,021	19	8,587	14	3,870	10	4,162	9	4,334	6
None	9,575	24	5,856	18	8,758	15	5,409	11	7,846	8	6,889	11	5,511	14	7,249	15	11,617	15
Total	39,175	100	33,370	100	58,768	100	49,459	100	93,622	100	62,355	100	38,957	100	48,660	100	75,850	100
Average		1.33		1.47		1.54		1.76		1.90		1.69		1.58		1.54		1.40

4.3 Characteristics of households

We also conducted cross-tabulation analysis on a number of household characteristics and the year the house was built (see Table 3). Gender is the first characteristic examined. The results for gender show a fairly consistent gender split, indicating that the year the house was built had little impact on the gender split. A similar result was found for age. The average age for each of the housing groups was shown to be 37-41 for all housing built before 1995. The average age falls to 35 for those living in housing built between 1996-00 and to 33 for those living in housing built from 2001 to 2006, of which, almost 60% are in the 25-34 range compared to 44% in the earlier periods and under a third for all housing constructed pre-1996. Despite this, the results demonstrate a fairly consistent age profile, suggesting that an individual's age has little impact upon the age of the house the individuals chooses to live in.

The SEG (socio-economic group) variables are ordered in highest profession first. A full definition of each of the SEG variables can be found in Table 5 in Appendix 1. The results in Table 3 demonstrate that there is very little difference in the distribution between the SEG variables. As with the gender and age variables, this result suggests that socio-economic grouping has little impact upon the age of the house a person lives in. The final set of variables examined in Table 3 represents the number of individuals' per-household. The average number of residents for each of the housing groups is also calculated. The results show that the average number of people per-household ranges from 2.7 to 3.6. As before there is very little difference in the average number of people per-household. Housing stock built 2001-2006 was shown to have the lowest average number of residents of 2.7.

TABLE 3 Household characteristics

Year built	Before 1919		1919-40		1941-60		1961-70		1971-80		1981-90		1991-95		1996-00		2001-06	
Gender	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Male	21,665	54	18,183	54	32,254	54	27,439	55	51,977	55	33686	54	21450	55	26965	55	40348	53
Female	18,132	46	15,594	46	27,078	46	22,441	45	42,435	45	29199	46	17856	45	22137	45	36480	47
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62885	100	39306	100	49102	100	76828	100
Age																		
15-24	4,040	10	3,795	11	7,389	12	6,373	13	15,384	16	10021	16	4516	11	5641	11	9191	12
25-34	12,868	32	8,744	26	13,929	23	12,273	25	22,999	24	15850	25	13105	33	21514	44	45704	59
35-44	9,373	24	8,254	24	15,038	25	11,593	23	15,319	16	13779	22	12798	33	15295	31	15853	21
45-54	8,003	20	7,795	23	14,574	25	9,733	20	21,380	23	16550	26	6827	17	5015	10	4326	6
55-64	4,654	12	4,390	13	7,128	12	8,034	16	17,860	19	6134	10	1856	5	1418	3	1495	2
65+	859	2	799	2	1,274	2	1,874	4	1,470	2	551	1	204	1	219	0	259	0
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62885	100	39306	100	49102	100	76828	100
Average		39		40		40		41		40		39		37		35		33
Socio-economic grouping																		
SEG1	7,551	19	6,087	18	9,688	16	8,567	17	14,688	16	11000	17	8262	21	9786	20	15001	20
SEG2	6,614	17	3,859	11	4,912	8	3,884	8	6,066	6	5136	8	4383	11	5435	11	9092	12
SEG3	7,110	18	5,229	15	7,691	13	6,704	13	11,659	12	8428	13	6136	16	7370	15	12135	16
SEG4	8,686	22	8,720	26	16,590	28	14,285	29	28,676	30	17906	28	10317	26	12784	26	20141	26
SEG5	2,083	5	2,739	8	6,134	10	4,961	10	11,196	12	6346	10	3125	8	4069	8	6044	8
SEG6	2,384	6	2,571	8	5,608	9	4,438	9	8,694	9	5208	8	2466	6	3449	7	5314	7
SEG7	1,261	3	1,345	4	2,686	5	1,758	4	3,442	4	2386	4	945	2	1451	3	2220	3
SEG8	1,833	5	1,534	5	2,951	5	2,626	5	4,779	5	2840	5	1683	4	2135	4	2440	3
SEG9	156	0	86	0	90	0	77	0	176	0	108	0	61	0	71	0	116	0
SEG10	52	0	31	0	44	0	77	0	104	0	67	0	34	0	57	0	112	0
SEG11	2,067	5	1,576	5	2,938	5	2,503	5	4,932	5	3460	6	1894	5	2495	5	4213	5
Total	39,797	100	33,777	100	59,332	100	49,880	100	94,412	100	62885	100	39306	100	49102	100	76828	100
No. of people per household																		
1	6,460	16	3,624	11	4,762	8	2,947	6	4,425	5	5,174	8	3,916	10	4,556	9	10,626	14
2	12,260	31	8,336	25	13,548	23	10,498	21	16,809	18	12,753	21	10,103	26	14,516	30	32,815	43
3+	20,749	53	21,526	64	40,497	69	36,062	73	72,174	77	44,251	7	25,035	64	29,787	61	33,072	43
Total	39,469	100	33,486	100	58,807	100	49,507	100	93,408	100	62,178	100	39,054	100	48,859	100	76,513	100
Average		2.9		3.2		3.3		3.4		3.6		3.5		3.2		3.1		2.7

4.4 Estimating the impact of house on transport patterns

Table 4 presents the results of the three models estimated to examine the impact of a number of key household and location characteristics on mode choice. Three binary variables were created, the first variable examines those that walk or cycle versus those that use all other modes, the second examines those that take public transport versus those that take all other modes, and the last variable examines those that drive versus those that use all other modes. The purpose of this exercise was to determine the relative impacts of a number of variables on mode choice to determine what if any impact the age of housing stock has upon mode choice.

The first set of explanatory variables estimated examines the impact of the distance travelled on mode choice. The results show that distance has a significant impact on mode choice and demonstrates those that walk or cycle are more likely to travel 0-10km to travel to work. Whereas, as one would expect, those that take public transport or drive were shown to travel further distances to work. The departure time variables show that those that walk or cycle to work were shown to be most likely to depart for work after 08:00 am, this result makes intuitive sense as those that use this mode were shown to travel the shortest distances, 2 kilometres on average. The results show that public transport users were most likely to depart between 07:00-07:59, and those that drive were most likely to depart before 06:59.

The bus stop density variables (representing the number of bus stops per electoral district) show that those that walk or cycle and those that use public transport were more likely to live in areas with a high number of bus stops available. A similar result was found for those individuals living in an area with a rail station. Those that drive where shown to be less likely to live in an area with a large number of bus stops or have a rail station available. This finding suggests that those drivers are more likely to live in an area with no rail option and few public transport options. The housing variables are examined to ascertain how and if the year a house was built impacts upon mode choice. The results show that those who walk or cycle to work, were found to be more likely to live in older housing stock. The opposite result was found in the drive to work model, with those living in newer housing stock shown to be more likely to drive to work. The results for the public transport model are mixed in relation to the impact that the year the house was built on the likelihood that the resident will use public transport. The results show that those living in housing built after 1980 was less likely to use public transport.

The number of cars per-household was shown to have a significant impact upon the mode of transport used. The results show those that walk or cycle or take public transport were most likely to own one car, while those that drive were shown to be more likely to own multiple cars. The final results presented in Table 5 measure the impact that urban density has upon mode choice. Unsurprisingly, those that walk or cycle to work were shown to be less likely to live in low density areas, public transport users were shown to be more likely to live in mid-density areas. As one might expect those that drive to work were shown to be much more likely to live in low density areas. However, it is a troubling finding for policymakers interested in promoting sustainable development patterns given that fully 52% of housing units built between 2002 and 2006 were in areas containing less than 3,000 persons per square kilometre and 30% were in areas with less than 1,000 persons per square kilometre - a rise from 14% of housing units in the previous census period. The results also show that the age of housing stock has an impact upon mode choice, but not to the same extent of other characteristics such as distance travelled, car availability and urban density.

TABLE 4 The impact of housing on the mode of transport

		Walk or cycle	Public Transport	Drive
	Intercept	-2.029***	-.714***	-2.038***
Distance	0-10 km	2.083***	-.175***	-.531****
	11-20 km	-1.044***	.469***	.332***
	21-30 km	-1.283***	.223***	.133***
	31+ km	0b	0b	0b
Departure time	Before 06:59	-0.694***	.299**	.128***
	07:00-07:59	-0.585***	.646***	-.132***
	08:00-08:59	0.009***	.265***	-.105***
	After 09:00	0b	0b	0b
Bus stops	None	-0.133***	-.325**	-.124***
	1-5 stops	-0.006**	.310***	0.14***
	6-10 stops	0.032***	.261***	0.116***
	11-20 stops	0.201**	.259***	-0.219**
	21 + stops	0b	0b	0b
Rail available	Yes	0.178***	.172***	-.220***
	No	0b	0b	0b
Year housing built	Before 1919	0.031***	-0.201**	.110***
	1919-1940	0.164***	0.074**	.194***
	1941-1960	0.378**	-0.007***	.253***
	1961-1970	0.442**	0.047***	.258***
	1971-1980	-0.429*	0.031***	.267***
	1981-1990	-0.404**	-0.072***	.343***
	1991-1995	-0.357**	-0.156***	.392***
	1996-2000	-0.322***	-0.216***	.425***
	2001 or later	0b	0b	0b
Number of cars available	One	1.013***	1.167***	2.946***
	Two	-1.911***	-2.012**	3.831***
	Three or more	-1.969***	-2.017**	3.826***
	None	0b	0b	0b
Residential density	Less than 1000 per km^2	-1.263***	.088***	1.021***
	1001-3000 per km^2	-1.118***	.257***	.935**
	3001-6000 per km^2	0.091***	.342***	.824**
	6001 - 9000 per km^2	.500**	.185**	.534***
	9001 – 12000 per km^2	.204***	.043**	.244**
	12001 + per km^2	0b	0b	0b
	-2 log-likelihood at convergence	-1478.251	-2014.142	-2197.014
	R2	.189	.137	.224
	N	414,173	414,173	414,173

*** Significant at a 1% level: ** Significant at a 5% level

CONCLUSIONS

Over the last decade and a half, the Irish government and local Dublin policymakers faced almost unprecedented economic growth. As we have seen, the latter part of the boom was characterised a rapid increase in the housing stock. At the same time, they committed themselves to ensuring sustainable patterns of development and transportation through a number of very ambitious strategies. However, as we have seen, the attempt to better integrate transportation and land use planning has been hindered by the diffuse nature of policymaking in the Dublin Area. Accordingly, it is possible that a large opportunity to reshape these patterns in Dublin has been lost. We have seen that almost a fifth of all houses built in this area since Irish independence were built in the five years up to 2006. This suggests that policymakers had a tremendous contemporaneous opportunity to influence transport and development patterns in a way that would likely have brought significant changes. Yet, the results of this research show that individuals that live in housing built during that period were more likely to exhibit less sustainable commuting characteristics and most of that housing was built in low density areas with fewer services. Commuters living in the newest housing stock, who are also likely suffering the effects of negative equity and, as a result are less mobile (42), are also the ones with the least sustainable transportation patterns. One of the most compelling findings is in relation to where the newest housing stock was situated. Over 50% of all new housing units were built in areas with existing population densities were low. These areas typically lack the services available to residents in higher density areas and to access those services, residents will more likely need the use of a car. Accordingly, it is not surprising to see that residents in these areas are more likely to drive to work. Driving commuters also have longer commute times and leave earlier to commute to college, school or work. In contrast, residents that use public transit or walk are more likely leave later in their morning commute.

This should give tremendous pause for thought on behalf of Irish policymakers, despite many strategies to encourage sustainable development and transportation patterns, the development patterns were, as one researcher called it, laissez-faire. The diffuse nature of policymaking in the Dublin area has often been cited as the main administrative barrier to integrated planning. Given the recent vintage of much of the housing, policymakers should, at the very least, look towards the mistakes of the recent past, and investigate concrete ways to reverse the backwards steps of recent years. This will require a much larger investment in integrated land use and transportation planning than hitherto exhibited and the process should include ways to implement already existing strategies and mitigating the mistakes of recent years.

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A METHODOLOGICAL FRAMEWORK FOR THE STUDY OF HOUSEHOLD RESIDENTIAL LOCATION CHOICE AND TRAVEL BEHAVIOUR

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ABSTRACT

The aim of this paper is to examine the relationship between housing location choice and travel behaviour at a disaggregate level. Evidence from existing research studies show that land-use planning patterns influence mode choice and patterns of mobility. Residential location is also an important factor in land-use planning which has a long lasting effect on household travel behaviour. This research explore the notion of self-selection which encompasses household residential location choice decisions matched to a households travel behaviour i.e. that car owning household has more flexibility in their choice of housing location. The paper explores the literature on household location choice and travel behaviour and then develops a conceptual model to assess the causal effect of household choice on housing locations and travel patterns. The paper also examines the importance of attitudinal and socio-demographic factors which contribute to household mobility patterns and residential location choice. By identifying the common methodological flaws the paper then propose the methodological framework and rational for residential self-selection research. The paper concludes with key findings for policy development.

Keywords: Land-use planning, Travel behaviour, Housing location choice

1 INTRODUCTION

Choice of residential location is a multi-dimensional decision for any household. During the last three decades, researchers are attempting to find out the exact relationship between attributes of built environment and household travel behaviour. The motivation of this interest is based on the possibility that design policies associated with land-use planning may be used to manage, control and shape individual's travel behaviour and then overall aggregate travel demand (Bohte *et al*., 2009; Litman, 2009). There are some studies which look at urban form factors and the effect of land uses such as *smart growth*, mixed land-use and street design on the travel patterns of households. Detailed review of such studies has been conducted by leading scholars with conclusion that there is indeed a significant impact of land-use attributes on the travel behaviour. At least some link exists between the characteristics of residential locations and travel behaviour (Badoe and Miller 2000; Crane 2000; Stead and Marshall 2001; Ewing and Cervero 2001; Handy 2005; Cao *et al.,* 2008). These studies show that among

others, socio-demographic characteristics of family and urban form attributes formulate the households travel behaviour.

When investigating the direction of causality between residence location choice and travel behaviour two questions are of particular importance (i) does housing location choice affect travel behaviour and/or vice versa and (ii) after the causality has been established in either direction should land-use planning policies be based on expected transport impacts? Such questions are of key interest for policy makers. For example, the Dutch government has adopted the well-known 'ABC location policy'. The reason for this policy is that spatial planning can be used to influence the amount and mode of travel. The objectives for adopting this policy are environmental and economic because good accessibility and a clean environment are vital for the economic and social functioning of the country (Schwanen et al., 2004). Planning Policy Guidance (PPG)[1] in the UK on transport is similar to ABC policy in spirit but less specific. The guidance deals with the reduction in the length and number of car journeys and encourages alternate means of travel which have less impact on the environment and reduce car dependency (Owens, 1995).

The interaction between land-use and transportation has been a matter of interest for many years from both theoretical and empirical perspectives among the researchers. Land-use planning as a mobility strategy is still a matter of debate. Land-use planning is a key element for achieving sustainability in an urban context and housing location is one of key component. Recent literature shows that sustainable urban development can only be achieved when transport and land-use are treated simultaneously (Banister 2008). The land-use planning stimulates the need for transportation and the supply of transport infrastructure shapes urban form. Urban planners and transport policy makers face a challenge to reduce overall mobility and as a result carbon emissions without compromising economic growth.

The relationship between urban form and travel behaviour is complex and there are many factors (variables) involved from both sides (TRB 2009). Bhat and Guo (2007) have mentioned three elements which represent the complexity of this relationship. These elements are (i) the multi-dimensional nature of the relationship between both (ii) the influence of decision maker characteristics and (iii) the spatial scale of analysis. Due to this complexity researchers do not have harmony in opinion about the intensity of causality between residential location choice and travel behaviour (Ewing and Cervero, 2001; Dieleman *et al.*, 2002). Here there is also an argument about residential self-selection concerning travel behaviour which refers to how households choose a residential location that conforms to their travel-related attitudes. It makes a significant contribution to this complexity and ignoring this can lead to wrong estimation of the impacts of urban form on travel behaviour.

Emerging research studies have addressed the relationship between urban

[1] In UK Policy Planning Guidance (PPG) is a statement of Government policy and principle towards the aspects of the town planning and transport framework.

form and travel patterns. In response, land use planners have recommended certain policy measures to reduce travel demand such as:

Push and Pull policies: Car user's attitudes can be changed by pull (by making the car unattractive) and push (by making public transport attractive) strategies, because attitudes are based on the weighing of the (perceived) costs and benefits of various alternatives.

(ii) *Hard and Soft measures:* An effective way to change the behaviour of people is with 'hard measures' like doubling the fuel price or doubling the public transport frequency. For 'soft measures' (e.g. education, information and motivation) to be effective in changing the attitudes of people, a comprehensive and integrated urban form policy is required along with the transportation demand management strategies.

(iii) *Sustainable Communities:* It means development policies that encourage dense and mixed land-use, car free developments where appropriate and establishment of home zones - strict controls on vehicles within residential areas (e.g. low speed limit such as 10 mph). The smart growth development strategies have impact on numbers and length of car trips.

(iv) *Opportunities and constraints*: policies based on opportunities (for environmental friendly modes) and constraints (car mobility) are more effective to change the human behaviour such as safe riding paths for cyclists and pedestrians and maximum car parking standards rather than minimum.

It is considered that households make a trade-off between residential location and the cost of commuting to access the goods and services. Households make their decision about a particular transport mode and residential choice on the basis of a systematic analysis of available alternatives. The advantages and disadvantages of a particular site can encourage or discourage adoption at a specific behaviour. Local development policies therefore need to provide certain kinds of opportunities at the micro level (e.g. neighbourhood design), in order to influence behavioural change at the macro level. The impacts of these interventions can be significant for society but there is still a need for research to explore the effectiveness of these policies.

The aim of this paper is to examine the international research evidence concerning the factors which drive the residential location choice behaviour of households. It includes empirical research which discusses travel behaviour from the perspective of three main factors namely: planned behaviour (e.g. desire and attitude), land-use planning factors and socio-demographic characteristics. The rest of the paper has been organised as follows. Section two and three examines the theoretical linkage between land-use planning and travel behaviour. The role of socio-demographic and attitudinal factors has been assessed in section four. In section five, an importance of household self-selection has been examined and a conceptual model of household travel behaviour and housing choice preferences has been developed by focusing on personal and social characteristics which contribute to household mobility patterns and location choice. Section six deals with overall research methodologies and rational and

in the last section conclusion with key findings has been presented.

2 CHOICE BEHAVIOUR: THEORETICAL PERSPECTIVE

A theoretical link between land-use planning and travel behaviour is important because theories provide the basis for understanding hypotheses. Theories can also explain the relationship between variables. The choice behaviour literature shows vast disagreement about the theoretical relationship between travel behaviour and land-use planning (Handy, 2004a). After many years of research, a common understanding is still missing, how the urban development in the region stimulates the needs for transportation and the supply of transport infrastructure makes the shape of urban form. For many years, the researchers have developed travel pattern theories about travel mode choice in the context of economy, geography and social aspects. It is pragmatic to look in detail these theories to understand the travel activity of the household. Before going to the depth of land-use planning impacts on travel behaviour, it is important to look at the theoretical perspective of choice behaviour first.

2.1 Planned Behaviour Theory

Individual/household choice behaviour is mostly influenced by two factors, individual characteristics and the surrounding environment. Many studies show that individual travel choice depends on demographic factors (age, gender) and socioeconomic characteristics such as income level and education. Other internal and external factors which are also important in deciding the travel mode choice include: (i) attitudes, preferences, motivations and skills related to behaviour (ii) constraints or opportunities that have a direct impact on making the behaviour easier or more difficult in relation to a trip (iii) and the incentives and disincentives (Ajzen, 1991).

Psychological studies explain behavioural responses by searching for factors that may explain people's choices including the external and internal factors which affect travel behaviour. One of such study is *planned behaviour theory* (PBT) (Ajzen, 1985; Ajzen 1991) which provides important information about attitude measurement and the prediction of human behaviour. PBT is probably the most frequently used theory in transportation on travel behaviour (Bamberg *et al*., 2003; Gardner and Abraham, 2008) which is derived from the expectancy-value theory (Bohte *et al*., 2009). Expectancy-value theory says that people determine the expected value of their action by cognitive evaluation (e.g. public transport is environmentally friendly) multiplied by the affective evaluation of the attribute (e.g. using an environmentally friendly travel mode is good). Therefore, it is assumed that people choose the travel mode and residential location which they feel has the highest expectancy-value for them (Gärling and Garvill, 1993). The application of PBT to travel choice and residential choice helps in understanding how people make decisions.

According to the PBT most actions can be viewed as deliberative and planned behaviour. Behavioural intentions are influenced by people's attitudes, subjective norms and perceived behavioural control. PBT says that individuals make their decision about a particular transport mode and residential

choice on the basis of systematic analysis of available alternatives. Behavioural intention comprises of three main factors namely: attitude to the behaviour (individual's positive or negative evaluation of performing a behaviour), subjective norm (perceived social pressure to perform the behaviour) and perceived behaviour control (perception of weather it is feasible to perform the behaviour).

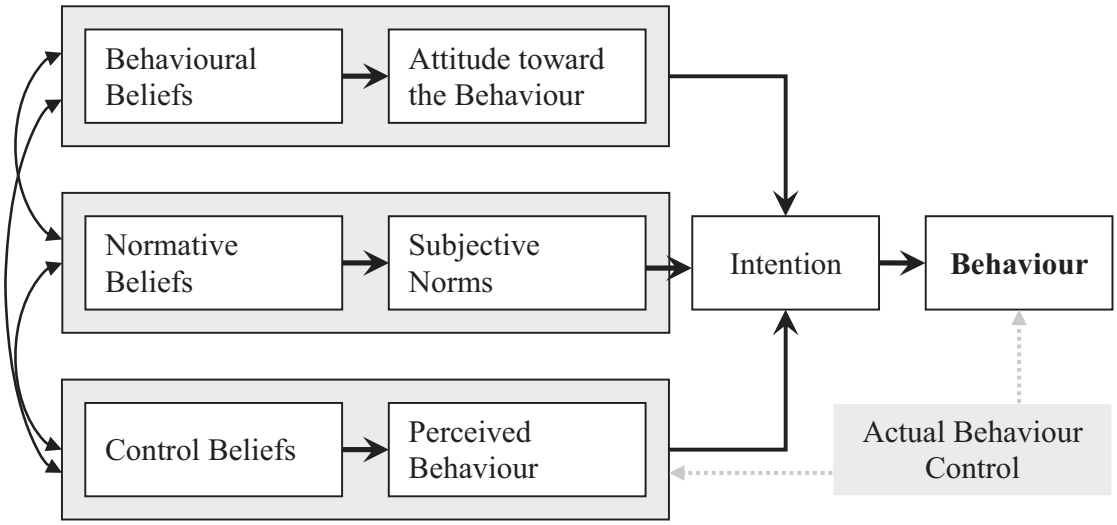

Figure 1- The Theory of Planned Behaviour (Ajzen, 1991)

Subjective norms mean an individuals' perception about expectations and opinions of other people (like family members or friends). Social norms affect people's behaviour through intentions, especially when they are not sure about appropriate behaviour. People who are sure about which behaviour to perform are less affected by social norms and they have a low possibility of changing their behaviour.

Perceived behavioural control refers to a person's perception about his/her own capability to perform an act (Forward, 1997). According to the theory, perceived behavioural control affects people's intentions, which subsequently influences behaviour. As presented in the figure 1, the broken arrow between perceived behavioural control and behaviour shows that the effect on behaviour can be both direct and indirect. There are four additional variables that are important and they include environmental concern, moral norm (internal notion whether it is right or wrong to perform the behaviour), behavioural norm (perception of other's behaviour) and habit (willingness to use a particular transport mode to travel to a variety of destinations).

3 LAND-USE PLANNING AND TRAVEL BEHAVIOUR

The rise in transport demand is encouraged more by the increased spatial separation of homes and workplaces, shops and schools than by any rise in trip making, particularly in low density, sprawled cities (Banister, 2008; Owen, 1992). Rapid growth in car ownership has permitted more dispersed patterns of urban development; these land-use patterns in turn require longer journeys for most daily activities and have become increasingly difficult to serve by energy-efficient modes of

transport (Guo and Bhat 2007; Owens, 1992).

The urban system is a dynamic entity and its spatial structure evolves overtime. There are some actors which are responsible for this evolution namely; housing, public institutions and activities centers. Location decisions of these actors can affect urban form and subsequently transport choice. Normally travel behaviour is a result of three main factors (Van Wee 2002; Stead and Marshall, 2001 and Stephen, 1993) as shown in the Fig. 2. The figure illustrates the relationships between the main determinants. All three categories are influential in all directions. Changes occurring in one of the three categories of determinants could have an impact on the complete system (Van Wee *et al.*1997; Van Wee, 2002).

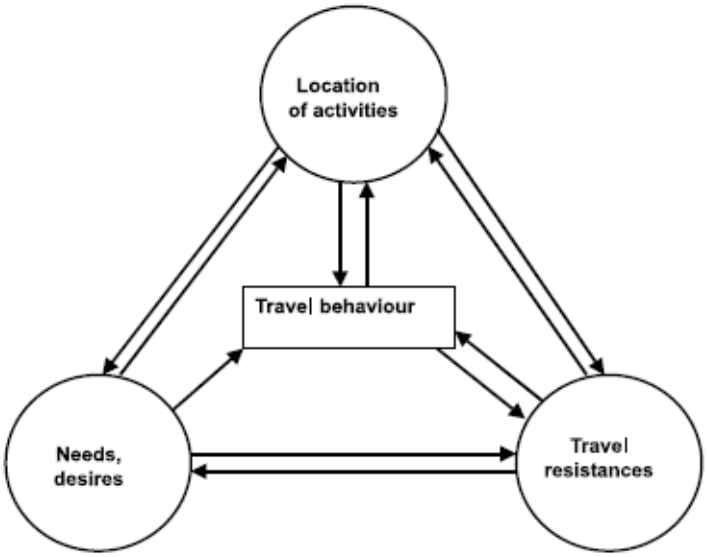

Figure 2 - Relationships between activity locations, needs and desires, transport resistances and travel behaviour (source: Van Wee *et al.*1997)

Generally mobility can be defined as a movement of people and goods in space and time (Chapin, 1974). Activities are located in the 'space' of different land-uses and people need to spend time on these activities. Some studies show that mobility is also determined by demographic, cultural and socio-economic aspects of a region, besides the temporal and spatial characteristics. These characteristics create the demand for travel and define how and why people travel and what modes they use for travelling.

Many studies show that *smart growth* development (also called *new urbanism* in US which is a set of sustainable planning practice based in more compact, public transport accessible and multi-model development) can significantly reduce the need to travel (Erwing *et al.,* 2007; Litman, 2009; TRB 2009). It is believed that travel is a derived demand, people need to travel long distances because jobs, services and other activities centres are located far away from their place of residence. People rely on cars for their daily activities even for short trips because there is no other viable option available

such as transit oriented development and mixed use development.

4 HOUSEHOLD'S RESIDENTIAL CHOICE FACTORS

In the previous sections of this paper our discussion formed on the human psychology and physical environment perspective of household residential choice. Other factors which influence household' residential choice, are socio-demographic characteristics and the social environment such as, opportunities/constraints and incentives/ disincentives (Michaelson, 1977). According to some studies, housing characteristics such as cost, size and location are main choice factors (Timmersmans, 1988). Some researchers have opinion that life cycle - rather than economic motives - is the main explanatory factors in housing moves (clark and Van Lierop, 1987; Kijkamp et al., 1993) Residential location choice depends also on at least three other factors such as (*a*) attitudes, preferences, motivations, and skills related to the behaviour; (*b*) opportunities or constraints that make the behaviour easier or more difficult to perform; and (*c*) incentives or disincentives that encourage or discourage the desired behaviour relative to competing activities (Handy 2004; Brun and Fagnani 1994).

4.1 Demographics Characteristics

People move their home location because of dissatisfaction with their current location or because a new location offers benefits not available at their current location. They are encouraged to move by changes in their personal (e.g. job change) or household circumstances (e.g. marriage, birth of child) or changes in their neighbourhood (more environmental friendly, quietness). Households are pulled to new locations by their aspirations for better housing or by opportunities that more closely match their needs and preferences. A move may occur because of a socio-economic change or social desire. For those households with children of school age, there is ample evidence that perceptions about the quality of schools influence locational decisions, as well as housing prices. Some studies point out that households make a trade-off between the amount of housing they can buy and the costs of commuting to access services (Hunt *et al.,* 1994; Sermons and Koppelman, 1998).

Because most households have budgetary constraints, housing costs and housing attributes (parking facility, number of rooms, lawn) are a primary factor in the locational choices they make. Housing costs vary with diverse factors of current location including size, quality, type, and age of the unit and the characteristics of the neighbourhood where it is located. Studies find that housing affordability is a primary determinant of the location of households, and people make trade-offs between housing cost and travel cost of access the different destinations (Kaysi and Abed, 2001; Cooper *et al*., 2001). Some studies addressed the residential choice issue by comparing housing attributes, residential environment and accessibility. The results of six case studies from the Netherlands suggest that accessibility considerations are significantly less important than housing attributes and attributes related to neighborhood environment (Molin and Timmermans, 2002). These findings however represent a discrepancy from

the results of other residential location choice studies (Gayda, 1998; Cooper *et al,* 2001; Walker *et al,* 2002).

4.2 Socio-economic Characteristics

The socio-economic differences between different types of settlement also play an important role in transport choice (Headicar, 2000). Being a relatively prosperous society; it is easy to buy private car in most developed countries therefore the result is newer, expanding urban areas and in dormitory rural areas. This is reflected in much higher rates of household car ownership overall in developed countries including UK (Headicar, 2000; DfT, 2009). In the UK, two factors which are especially important in influencing the amount of car travel are the current lifestyle of younger generations and land-use planning (Headicar, 2000). A proportion of the difference in travel behaviour between settlement size categories will be attributable to such socio-economic differences rather than to settlement size in itself. This behavior is clearer when research conducted within two English counties is considered which suggests that socio-economic rather than land use characteristics account statistically for more of the variation in travel patterns (Stead *et al.,* 2000).

There are also large numbers of research studies available in literature, which deal with variety of socio-economic factors and their influence on travel pattern and residential location choice. After comprehensive review of studies, Stead and Marshall (2001) identify among others eleven types of socio-economic factors which impact on travel patterns. These socio-economic factors are interconnected with each other, and it is often difficult to separate the effect of one from another (Stead and Marshall, 2001). For example household income is linked to employment and this may influence car ownership and use. Car ownership and use is also further influenced by age and gender. Several studies have examined the impacts of socio-economic factors on travel pattern by using different methods and scales (Dunphy and Fisher, 1996; Kockelman, 1997). Socioeconomic characteristics such as income, age, gender, occupation have a significant impact on travel behaviour and must be adequately represented at a disaggregate level in models that attempt to estimate the impact of the built environment on travel behaviour (Stead and Marshall, 2001). Ewing and Cervero (2001) note further that socioeconomic factors are dominant in trip frequency decisions, whereas the built environment appears to be more influential with respect to trip length, while mode choice depends on both factors.

Overall, a combination of household socio-demographic characteristics, such as income levels, age of household members, and family size, interact with the housing opportunities available in a region to determine whether a household will move. Housing opportunities are a product of the type and quality of housing stock, the characteristics of neighbourhoods, and desired quality as well cost of public services.

4.3 Attitudinal Factors

Mostly all human being make mind towards or against something after the careful evaluation of situation. These evaluations can be affective evaluations, cognitive evaluations as well as behavioural responses. When it comes to the selection of residential location, it usually is impossible to identify the

exact role of travel related attitudes because with housing alternatives plenty of built environment attributes are also involved. As Lindberg *et al*., (1998) indicated the complexity of residential choice by mentioning that, '*different dimensions of housing attributes may not be evaluated independently of one another and therefore the evaluation of housing attributes in isolation from one another does not seem reasonable'*. On the issue of residential choice, most empirical studies have also measured current travel related attitudes rather than attitudes at the time of the residential choice to account for residential self-selection. Therefore, the whole interaction between attitudes, built environment characteristics and travel behaviour is important for sustainable transport policy.

4.3.1 Habit and Desire

Some other factors like *habit* and *desire* have been added into many other studies. Infact, habit is considered one of the most significant factors and several studies have demonstrated the role played by habits in travel behaviour (Naess, 2005; Gardner and Abraham, 2008). Some scientists have criticised TPB for neglecting the role of *habit* and *desire* in human behaviour (Perugini and Conner, 2000; Perugini and Bagozzi, 2004; Dijst *et al.*, 2008). It is considered that when any particular behaviour is performed repeatedly, it becomes habit, consequently individuals are guided by an automatic cognitive process and therefore decisions are influenced.

Several studies have looked the effects of contextual changes (residential parking policy, financial incentives) on habits, intentions and attitudes related to travel patterns and have found a mix of results. According to some researchers land-use policies may be helpful with 'pull and push' strategies to change attitude, as well as the habit of car use (Bamberg 2002; Fujii and Kitamura, 2003). But other studies show that it is hard to change the strong habit and as a result this habitual behaviour is a key barrier to reducing the car use (Bamberg *et al*., 2003; Bamberg, Rolle, and Weber, 2003; Matthies, Klockner, and Preissner, 2006). Some social behaviour experts have the opinion that objective advantages of car use like, higher speed, comfort, and flexibility are the main determinants of individual travel mode choice and consequently residential choice.

4.3.2 Lifestyle

Lifestyle is defined as individual pattern of behaviour towards the resources available (Salomon and Ben-Akeva, 1983, Ge and Hokao, 2002 & 2006). Individual have developed a particular lifestyle for self satisfaction. Lifestyle determines the travel patterns for all kind of activities like; work, education, social and recreational. Travel patterns of individuals are influenced by lifestyle which is considered a very stable characteristic that is very hard to change and is a prominent determinant for residential location choice (Ettena and Timmermans; 1997). Thus, in the long-term lifestyle choice is an important factor in determining mobility behaviour. Choice of life-style is long term decision while the daily travel choice is short term. Decisions about family formation, job and free time activities all mostly depend on life-style.

4.4 Opportunities versus Constraints

The role of opportunities and constraints at neighbourhood level has been discussed in detail in the health and physical activity literature (Handy 2004a&b; TRB 2002). Sustainable development of built environment can provide equal movement opportunities for motorized and non-motorized transport. For example, concerns about personal safety can reduce the modal share of non-motorized on the roads. Research studies have shown that cyclists perceive unsafe with car speed increases in urban region (TRB.2009 & 2002). Just providing opportunities for walking and cycling may not be sufficient to change behaviour unless the constraints related to use the opportunities cannot be omitted. Segregated land-use development and therefore long travel distances between destinations makes the personal car only viable option.

4.4.1 Incentives versus Disincentive

In a review article, Kearney and DeYoung (1996) summarize the results of 29 empirical studies evaluating the effects of different intervention strategies on commuter car use. The results indicate that material incentives and disincentives are successful strategies which can initiate rapid changes in travel behaviour. It is hot debate among the researchers how to change the household travel behaviour using financial instruments. 'Pull and push' policies (e.g. parking policy, congestion charges and subsidized public transport) have been introduced to encourage more sustainable patterns of transport. Incentives and disincentives policies can be introduced from a neighbourhood to a regional scale by lowering the cost of a desired behaviour and raising the price of an undesired behaviour. For example, walking and cycling can be encouraged by providing the safe designated paths and restricting the vehicle speed limit. If people perceive that the behavioural changes are impossible (reflecting little personal control), then push and pull policies will not be effective. Individual's behaviour also depends on the opportunities to perform the behaviour. Besides the actual opportunities, the perceived opportunities are also important in deciding whether to perform an action. For example, if people consider the public transport as unsafe then it cannot be perceived as a reasonable option, even though it might be a feasible alternative. Often pricing policies are considered to be able to change the opportunities that people have (Ubbels and Verhoef, 2003). Though the PBT claims that major source of behaviour determinants are attitude, subjective norms and perceived behaviour control, the empirical research (DfT, 2003) shows that they are hardly sufficient to provide a complete account for decision making process.

5 RESIDENTIAL SELF-SELECTION

Households may not only align their travel behaviour to the possibilities and constraints of their residential location, but also self-select themselves by choosing to live in residential locations that correspond with their travel related attitudes. For example, residents who prefer driving over using public transport may choose remote and spacious neighbourhoods, while households with a preference for public transport may opt for more urban residential locations within walking or

cycling distance of a railway station. Residential self-selection significantly contributes to the complexity of travel behaviour and links with housing location choice. Ignoring residential self-selection leads to an overestimation of the impact of the built environment. This is evidenced by several studies on residential choice which, using different research methods, have indicated that travel-related attitudes and preferences do indeed influence residential choice (e.g. Molin and Timmermans, 2003; Schwanen and Mokhtarian, 2007; Naess, 2009). Therefore it is essential that the issue of self-selection is discussed in some detail.

Residential self-selection (also called the Sorting effect) is related to travel behaviour and means how households choose a residential location that suits to their travel-related attitudes. In other words, self-selection refers to the *'tendency of people to choose locations based on their travel abilities, needs and preferences'* (Litman, 2005, p.6). Residential location choice is an important a long term decision for a family which affects the travel patterns in the long run. On the other hand, travel behaviour of households may be affected by the opportunities and constraints of a location. Research studies show that, for residential self-selection, people take decisions under the influence of two sources: socio-demographic circumstances and personal attitudes (Mokhtarian and Cao, 2008). For example, a location decision under certain financial limitations (job, budget to buy/rent the house) and a residential choice without any internal or external limitation.

Under the first assumption people (households and individuals) select an area and locate themselves accordingly and then based on a range of neighbourhood attributes, develop their travel behaviours. This means people choose the location under financial or time constrained reasons but not necessarily because of car ownership. Built environment attributes can play an important role in shaping the travel behaviour, but the problem with the above assumption is that it does not take a comprehensive view of how individuals and households make residential choice and travel decisions. In real life, it is clear that high density and mixed land-use developments with public transit are more attractive for the car neutral households and individuals. These types of households will use walking and cycling to pursue their daily activities if neighbourhood facilities are available.

The second assumption is based the strong personal preferences related to travel pattern. Travel behaviour of people and consequently residential location selection comes under personal attitude and then people fulfil their daily requirement accordingly, like visiting jobs, services and activities. For example, people with high car ownership prefer less crowded residential location and remote neighbourhood. These assumptions have been confirmed by many studies with different research methods, although disagreement exists about impact intensity of built environment attributes and household variables. Some recent studies show that travel related habits and preferences have a significant influence on residential self-selection (Molin and Timmermans, 2003; Schwanen and

Mokhtarian, 2007; Mokhtarian and Cao, 2008; Naess, 2009).

The correlation of housing choice and travel mode choice is an understudied area and researchers are divided about the exact causal effect of both. Numerous recent studies have found a significant association between the residential environment and travel behaviour (Scheiner J. 2009; Pinjari et al., 2009; Cao et al., 2009; Naess 2009). However, most of these studies confirm only the associative relationship between them and the disagreement exists in knowing whether the neighbourhood environment influences travel behaviour or travel pattern preferences affects residential choice. The above mentioned large amount of literature from US and Europe covers the impacts of residential location choice (neighbourhood facilities) on travel behaviour but the reverse effect has not been well documented in the literature. Accessibility is a dominant factor when selecting a residential location. Policies related to transportation and land-use planning can impact on the lifestyle of households in the specific area. The residential location preference is one of many variables thought to affect travel behaviour. The conceptual model for this study (Fig. 3) recognizes the complex relationships travel behaviour and housing location. The impact of many variables in particular context are still unknown, however some decisive factors are included: household's socio-demographic characteristics, personal attitude and habits and physical environment as shown in the conceptual model below.

As mentioned above, numerous studies have found a significant association between the built environment and travel behaviour. However, most of these studies confirm only the associative relationship between them and the disagreement exists in knowing whether the built environment influences travel behaviour or travel behaviour preferences and land-use patterns affects residential choice. If the later assumption is more dominant then the ability to use the built environment characteristics to change traveller's mobility patterns may be limited because the majority of people like suburban types of development and who prefer walking, may consciously choose to live in walkable neighbourhoods (Morrow-Jones *et al*., 2004).

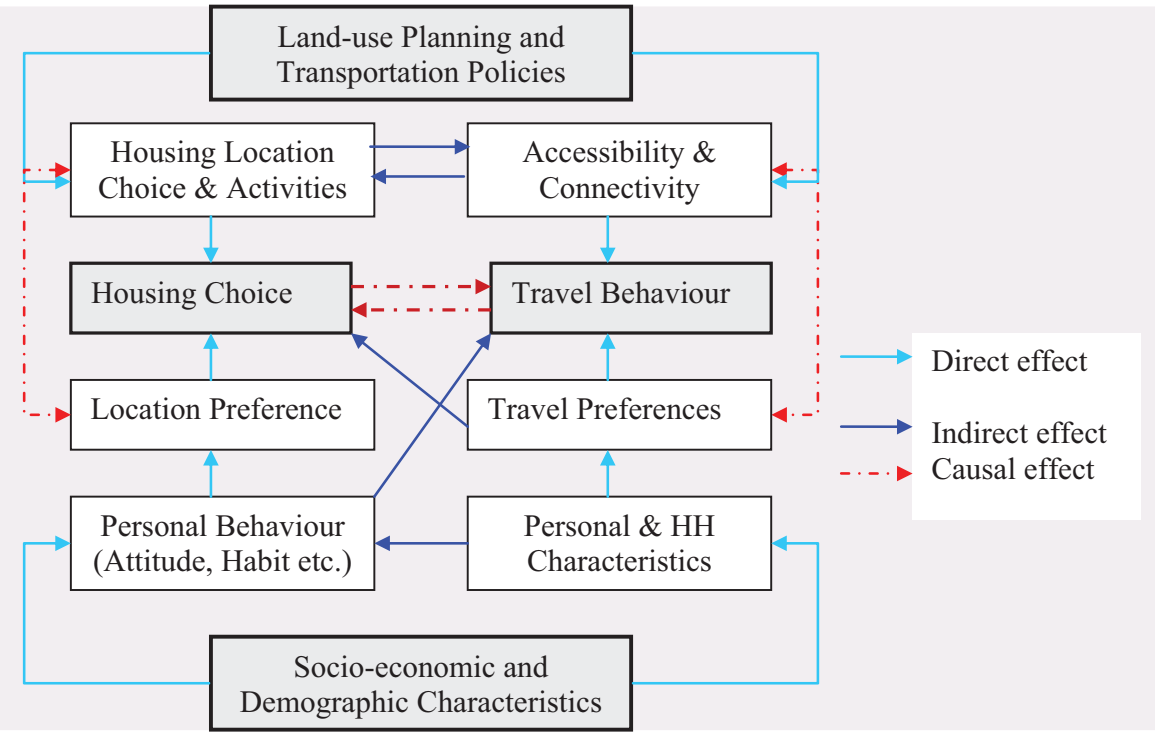

Figure 3 - Conceptual Model: Travel behaviour and Housing choice Preferences

6 METHODOLOGICAL FRAMEFORK

The literature review indentified the research gap in the area of housing location preferences and travel patterns. Three methodological flaws are most common. First, only few studies have systematically tried to differentiate carefully the influence of socio-demographic variables, neighbourhood built environment and transportation system on RLC. Often, there is a strong empirical relationship between socio-demographic variables and neighbourhood characteristics, implying that any correlation between travel patterns and neighbourhood characteristics might be spurious. Secondly, researchers have used different levels of aggregation (individual, neighbourhood, city) in the same analysis directly impacts the significance levels of the estimated regression coefficients, which may lead them to draw the wrong conclusions. Thirdly, many studies only look at trips for specific travel motives, such as work or shopping. Effects found on these types of trips do not shed light on the effects on total travel over all motives.

Based on the identified factors, this study evaluates two key themes. Firstly, households select an area and locate themselves accordingly; then based on a range of neighbourhood attributes, they develop their travel behaviours. Attributes of built environment thus play an important role to shape travel behaviour. Many empirical studies support this idea that high density and mixed land-use development with good public transit are more attractive for the car neutral households. Secondly, households make their housing location decision under strong personal mobility habit/attitudes and fulfil their daily requirements accordingly. This implies

that built environment attributes do not have any significant impact on RLC. Some recent studies stress the importance of habits and attitudes in self-selection (Naess, 2009, Bohte et al. 2009). Literature review in the previous sections has indentified the following key factors in connection with RLC and travel behavior namely;

- Housing unit (number of rooms, property type, garden, parking space etc)
- Neighbourhood index (distance to school, shops and activity centres)
- Residential Environment (quietness, green area, safety)
- Accessibility (PT connection, car dependency)
- Cost (housing cost, travel cost)
- Social Status (lifestyle, attitude)

Corresponding to international studies of residential self-selection (Scheiner, 2010; Pinjari et al., 2009; Cao et al., 2009) the above mentioned six key determinants are included in this research. Combination of quantitative as well as qualitative research can enable us to answer the questions concerning the residents' motivations and purposes for their ways of relating to their physical surroundings, notably the question about rationales for activity location and modal choice. This research study will avoid the potential methodological flaws by using the combination approach which is including focus group discussion (FGD), Q method, cross-sectional and time series analysis.

6.1 Overall Research Design

The research incorporates qualitative and quantitative analysis, the approach and methodology has been depicted in the figure 4. The methodology developed seeks to address the effect of housing location on travel mode choice on access to facilities, goods and services. In order to address the research problem the work is divided in two parts, the first part deals with focus group discussion and Q methodology while the second part deals with the application of revealed preference household surveys.

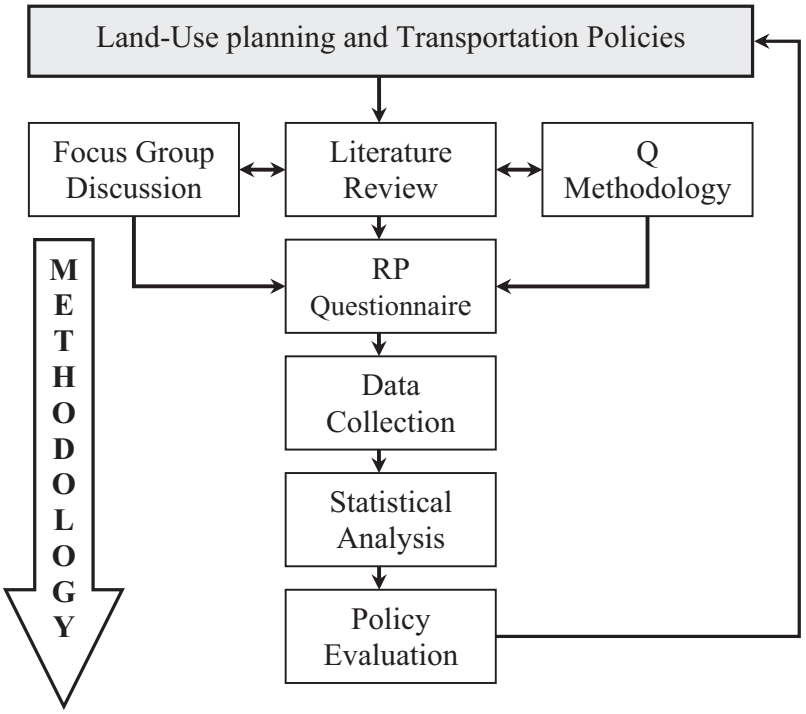

Figure 4 - Overall research methodology framework

Table 1 provides an overview of the types of information considered necessary in order to answer each of the research questions of this study. The table also shows the data sources used in order to acquire the desired information. This study uses focus groups and Q methodology to develop an understanding of the causality direction of residential self-selection -influence of different neighbourhood types on households' mobility patterns and vice versa- which is further examined using a revealed preference (RP) survey. The methodology will be based on a selection of neighbourhoods with variation of determinants resulting in areas with high versus low accessibility and land use mix.

Table 1 Research questions, information required and data sources

Research Question	Required Information	Source of Information
- Which neighbourhood qualities are important for households' choice of residential location?	Measurement of key variables such as: Perceived neighbourhood characteristics, accessibility to selected services and activities, commute trip characteristics, vehicles available to household	* Survey questions about the factors for neighbourhood characteristics such as: attractiveness, accessibility to PT & neighbourhood facilities, socializing, housing space * Technical visits * Qualitative FG discussion including questions about motives for choices of neighbourhood and modal choices * Ranking the most to least desired neighbourhood qualities through

		Q-methodology
- Do the household select a particular location or do the attributes of the particular location affect car ownership of the people moving to it?	* Socioeconomic characteristics of the residents and their attitudes to relevant issues * The location of the residence and its distances from various facilities * Travel behaviour before and after moving to the present dwelling * Residents travel activity to access services and activities centres	* Survey questions about socio-demographic characteristics of the residents, travel & environmental attitudes Estimation of residents' travel Survey questions about the and the distances travelled by their vehicles, and any changes in the amount of travel after moving
- What is the main residential location factors influencing the dwellers' choice of transport mode?	* The activities in which the residents engage, their location, and possible changes compared to previous residential location and/ or life situation * Location of activities, use of different modes of transport, and the considerations behind these choices	* Questions in questionnaires and qualitative interviews about activities, their location, * Qualitative interviews including questions about destinations and travel modes, and the motivations for these choices
- To what extent household's lifestyle and attitudinal preferences play role in residential location decision and travel behaviour?	* Information about Travel Preferences and residential preferences related to lifestyle and attitude/habit. * Information about number of cars/cycles/bus pass and socio-demographic (age, education, income etc.)	*Through the Q-methodology respondents will be pooled in 5 main categories namely: Pro-Transit, Car dependent, Environment concerned, Safety concerned and Status conscious. * Further through quantitative survey results will be analysed

Qualitative data will be derived through the focus group discussion (FGD) as well as using Q-method with the carefully selected household representatives from the case study areas. Focus group discussion will be helpful to inquire the decision of residential self-selection. RP Survey will be well designed and only relevant and to the point question will be included with easy to reply. Five neighbourhoods in Greater Belfast Metropolitan Area (GBMA) that differ with respect to neighbourhood design have been selected. From each case study area approximately the opinion of 200 household units will be collected through face to face survey. For survey households who had moved within the last 5 year will be selected. Data on travel behaviour, perceived neighbourhood characteristics, preferences for neighbourhood characteristics, travel preferences, and socio-demographic characteristics using a face to face household survey will be collected.

6.2 Methodology Rational

Different techniques have been used to investigate residential self-selection with respect to household travel behaviour such as direct questioning (focus group, in-depth interviews) (Handy and Clifton

2001), statistical control (Kitamura et al., 1997; Schwanen and Mokhtarian, 2005), instrumental variables models (Greenwald and Boarnet, 2001), discrete choice models (Cao et al., 2009), structural equations models (Bagley and Mokhtarian, 2002; Scheiner, 2010), and longitudinal designs (Handy, 2004; Cao et al., 2007 Naess, 2005&2009). In a comprehensive paper Mokhtarian and Cao (2008) has identified main advantages and disadvantages of each method and also noted the difficulties in actually quantifying the absolute and/or relative extent of the true influence of the built environment on travel behaviour. This research has adopted a combination of qualitative and quantitative. To understand household attitude and preference for residential self-selection qualitative approach (FGD and Q method) if carefully implemented, can provide very useful insights and perceptions, sometimes beyond what multivariate analyses can do. Mokhtarian and Cao (2008) have mentioned several limitations and weakness related to direct questioning (FGD) method such as small sample size. Moreover, some researchers (Galasiński and Kozłowska, 2010) based on (Gomm, 2004) questioned the validity of direct questioning data because of certain reasons such as;

- the participant does not know the right answer but gives an answer nonetheless;
- the participant gives an inaccurate answer which she/he thinks is accurate;
- the participant knowingly gives an inaccurate answer in order to present a favourable impression;
- the participant is unwilling to give (what s/he thinks) is the right answer, but gives another, perhaps one which the respondent thinks the interviewer wants;
- the participant refuses to give any answer at all;
- the participant doesn't interpret the question as it was intended and gives an answer based on a different interpretation, unbeknown to the researcher.

Mokhtarian and Cao (2008) have pointed out that direct questioning studies suffer with number of biases including; memory, consistency, saliency and social desirability. However, social science researchers defend the direct questioning method by arguing that these biases are equally possible and self-administered questionnaires survey data is equally vulnerable to the most of biases and limitation discussed above. Therefore, for better understanding the issue of residential self-selection the combination of qualitative as well as quantitative approaches are equally important for this research study. Qualitative methods, e.g. group discussions and Q methodology, will provide the subjective analysis (by segmenting households according to their lifestyle, preference and attitude) whereas questionnaire survey will focus on objective analysis (e.g according to socio-economic variables) of households. The advantages of Q-method are nowadays generally recognized (Raje, 2007) to investigate attitudinal variables such as households' lifestyle, and preferences. Moreover, accuracy in data quality can play an important role in understanding self-selection and decreasing 'errors' due to

ignoring self-selection. For data collection, Q-method is relatively simple technique compare to questionnaire survey requires low number of participants and therefore high chances to collect accurate data. Thus, the combination of qualitative and quantitative analysis will allow the researcher to estimate more precisely (i) the direct effect of person and household variables (e.g. age, income and household characteristics, but also attitudes) on travel behaviour; (ii) the impact of land-use variables (such as d mixed land use variables) on travel behaviour; and (iii) the effect of person and household variables on location choice, and via location choice on travel behaviour.

7 CONCLUSION

This paper has examined the literature related to household travel behaviour and the relationship with urban form. It investigates empirical evidence about the claims that land-use planning factors, household socio-demographic factors and social as well as personal preferences (attitude, habit) are the main determinants in the selection of household travel patterns and residential location choice. The analysis of the literature indicates that urban form factors have impacts on household's travel behaviour but that the role of socio-demographic factors and personal preferences are also significant which need to be quantified precisely. Another issue is self-selection; in the literature there are still limited numbers of studies which address the issue of self-selection principally. Households choose their residential locations based, among other things, on their preferences for modal split and/or preference for residential location. Here are key findings of this paper;

- The research implies that the relationship between urban form and travel behaviour is promising but it is premature to conclude that land-use planning policies can manage, control and shape individual's travel behaviour and then overall aggregate travel demand.

- Spatial planning certainly influences transportation behaviour, but explicit claims regarding any connection b/w residential location and mode choice are mainly speculative.

- Smart Growth is a hopeful effort to provide more consistent and sustainable planning, but disagreement exist among the researchers about its specific transportation behaviour claims.

- Better data and better empirical methods with the combination of qualitative/quantitative methods and models can give understanding the interaction of urban design and transportation.

- It is a challenge to balance the human need for residential location preference against the need for sustainable mobility.

In order to achieve sustainable travel behaviours, spatial planners need to design neighbourhoods (either constructing new or modifying the existing) that have sustainable patterns with houses that consider households various housing, travel and locality preferences.

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USING A MULTI-CRITERIA ASSESSMENT APPROACH TO IDENTIFY SUSTAINABLE TRANSPORT KEY ATTRIBUTES

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ABSTRACT

There is a great reliance on sustainable transport assessment in order to monitor the progress of achieving sustainability in transport systems. These assessments are varying both on nature and type. However, the selection of the appropriate assessment is a challengeable task not only due to the vast number of available assessments methods, but also because of the numerous attributes of sustainable transport and the relative weight of each attribute. These attributes have different influences on the way sustainable transport could be monitored and achieved. The challenge is to identify the key attributes of sustainable transport systems from user perspectives and to define their relative weight and priority of application. In this paper, the motive to apply the concept of sustainable transport from the transport policy perspective was introduced addressing all the different definitions of the concept in the UK transport context. Second, taxonomy of sustainable transport objectives was carried out introducing different objectives of sustainable transport in varied contexts. Third, sustainable transport indicators were introduced, derived and categorised. Fourth, a qualitative method was used to investigate users' perceptions and attitudes toward sustainable transport. Fourth, a multi-criteria approach was generated in order identify the relative weight and priority of application. Finally, the opportunities and challenges were discussed opening the way for future research.

Keywords: Multi-criteria approach, Sustainable Transport, User perception.

1 INTRODUCTION

The term sustainability as a principle in urban transport policy is frequently advocated but rarely defined (May et al, 2006). The term gained great value due to the role it plays in adding multidimensional tasks through the transport agenda (Hull, 2005). Several governmental publications – both in UK and EU – have advocated a sustainable approach to be applied in transport polices (May et al, 2006). After the rise of the new realism in UK transport policy. Especially after the introducing of integrated policy approach in the first white paper new deal of transport (DETR, 1998), the UK government identified sustainable transport as a key component of the new policy approach (Dft, 200a). Yet, the meaning of sustainability in the context of transport planning is still broad and it has been used in different contexts (Santos et al, 2010).

2 DEFINITIONS OF SUSTAINABLE TRANSPORT

Historically the term sustainable transport was derived from the origin of sustainable development as the expression of sustainability on the context of transport system. Although there are many trails to define sustainable transport, yet there is no single universally accepted definition (Castillo and Pitfield, 2010). Out of these trials (Black, 1996; Richardson, 2005) defined the term through adopting the Burdtland commission definition of sustainable development as; "*the ability to meet today`s transportation needs without comprising the ability of future generation to meet their transportation needs*". While, many writing (Mahmoud and Yousef, 2010; Litman, 2003; Loo, 2002; World Bank, 1996; OECD, 1996; WECD, 1987) pointed out the definition of the term in the context of the triple bottom life concept of economic, environment, and social equity. According to this definition, sustainable

transport system must insure achieving economic growth combined with both social justice and environmental concerns.

Reacting to this definition, many writing have investigated the specific objectives and features of sustainable transport and tried to break down the complexity of the triple bottom life. Gudmundsson and Hojer (1996) and Black (2000) explained the economic theme of sustainable transport, while Lautso and Toivanen (1999), Gilbert and Tanguay (2000), and Marsden and Bonall (2006) focused on the environmental concerns of sustainable transport. In addition May et al, (2001), and Castillo and Pitfield (2010) investigated the social attributes of the concept. However, even with the agreement of the triple bottom life concept, every individual and group address specific objectives of sustainable transport according to the role it plays in their context (Richardson, 2005).

3 SUSTAINABLE TRANSPORT OBJECTIVES

Policy makers introduced the term of sustainable transport in order to evaluate, measure and assess the positive and negative impact from traffic and transport as they are apparent now or in the near future (Gudmundsson, 2001). While, stakeholdersand operators used the term in order to achieve the policy objectives and monitor energy usage, consumption, CO_2 emissions and any harmful substances (Steg and Gifford, 2005). Due to the lack of any widely accepted definitions of sustainable transport – even with the agreement on the triple bottom life concept – there was an increasing concern to define the concept by proposing the targeted objectives of this term (Castillo and Pitfield, 2010). Gudmundsson and Hojer (1996), OECD (1997), Lautso and Toivanen (1999), Gilbert and Tanguay (2000), Black (2000), and Shiftan et al, (2003) introduced sets of different objectives which have been illustrated in Table 1.

However, May et al, (2001) introduced all these objectives under an umbrella project titled as the PROSPECT project. This project identified five main objectives of sustainable transport system as: liveable streets and neighbourhoods, protection of the environment, equity and social inclusion, health and safety, and support of vibrant and efficient economy. Till now some writing argued that the objectives of sustainable transport systems are still wide ranging and varying within the context, time, locality, and public awareness (Abolina and Zilans, 2002).

Table 1. Sustainable transport objectives

Source	Objectives
Gudmundsson and Hojer 1996	- Maintain natural resource base - Define usage levels and usage patterns - Maintains the productive capital base for future generations - Improves the quality of life
OECD 1997	- Integrates land use and transport planning - Minimises resource usage - Contributes to social equity - Supports economic growth - Maximises health and safety
DETR 1998	- Reduce pollution from transport - Improve air quality - Encourage healthy life style by reducing reliance on car - More cycle and walking schemes - Reduce noise and vibration from transport
Lautso and Toivanen 1999	- Reduces congestion - Minimises consumption of natural resources - Reduces pollution - Maintains health and safety
Black 2000	- Reduces air pollution - Meets mobility needs - Minimises accident
Gilbert and Tanguay 2000	- Minimises noise - Limits waste within defined targets. - Minimises usage of non-renewable resources - Maximise the usage of recycling materials. - Minimises land usage. - Maintains ecosystem and general health - Meets individuals and society basic needs - Consistent with human health - Availability of all transport modes - Provides access to all services - Ensures that mobility needs are met safely - Supports economy
May et al, 2001	- Liveable streets and neighbourhoods - Protection of the environment - Equity and social inclusion - Health and safety - Support of vibrant and efficient economy
Shiftan et al, 2003	- Reduces energy consumption - Minimise air pollution. - Protects wildlife and natural habitats - Improves accessibility to employment, social activities, etc - Maximises the availability of public transport to population - Decreases road transport accidents
Marsden and Bonall, 2006	- Improve air quality by meeting Improve air quality by meeting UK national air quality strategy objectives for carbon monoxide, lead, nitrogen dioxide, particles, sulphur, benzene and 1-3 butadienes - Reduce noise and vibration - Triple the number of cycling trips compared with a 2000 base
Castillo and Pitfield, 2010	- Liveable streets and neighbourhoods - Protection of the environment from transport pollution - Social equity and social activities inclusion - Maximises Health and safety - Support economic growth

4 SUSTAINABLE TRANSPORT INDICATORS

In order to monitor and assess the performance of any sustainable transport system, define indicators for each objective is an essential task. Reacting to this, indicators have been generated in many contexts (May et al, 2008). Although these indicators give the ability to capture the multidimensionality of the system and break it down into manageable items, it is still challengeable to identify and use these indicators for two main reasons; first, the numerous existing indicators of sustainable transport and the vast subsets it contains. Second, the indicators give only partial analysis to the whole system and coherent correlation between all indicators must be achieved in order to understand the whole picture (Castillo and Pitfield, 2010).

However, Castillo and Pitfield (2010) identified on the ELASTIC framework initial list of 233 indicators of sustainable transport system based on nine sources illustrated in Table 2. In addition, an evaluation and pair wise comparison of these indicators have been carried out using the ELASTIC framework. Castillo and Pitfield (2010) used the same five objectives of sustainable transport system identified in the PROSPECTS project. This framework evaluated the sustainable transport indicators form both academic and planners perspectives. In which a short list of 20 indicators of sustainable transport in the UK context have been introduced and ranked which are illustrated in Table 3.

However, both policy makers and stakeholders need to understand how consumers perceive and evaluate these indicators. Attitude towards transport is an important determinant for evaluating the system (Beirao et al, 2007). From the service providers' perspective it is essential to identify the most important attributes of service quality that are perceived by current and potential users. However, the specification of a set of relevant attributes is a challengeable task and it is important to identify their relative weight and influences on users' satisfaction (Prioni and Hensher, 2000). Yet it remains a challenging and important research area (Hensher et al, 2003). It is important to understand the different user evaluation for the same service, and to define the influence on their satisfaction by each element (Andreassen, 1995; Jensen, 1999; Anable, 2005).

Table 2. Initial list of sustainable transport indicators (Castillo and Pitfield, 2010)

Source	Indicators
- Modelling for sustainable cities: the transport sector (Kupiszewska, 1997)	32
- Indicators for the integration of environmental concerns into transport policies (OECD, 1999)	27
- Indicators of transport and environment integration TERM 2002 (European Environmental Agency, 2002)	38
- Sustainable Transport Indicator Project, CST (Gilbert et al., 2002)	14
- The 'Civilising Cities' initiative (Jones et al., 2003)	15
- PROSPECTS project's methodological guidebook (Minken et al., 2003)	19
- Securing the future (Department for Environment, Food and Rural Affairs, 2005)	68
- Local quality of life counts (Department of the Environment, Transport and the Regions, 2000)	12
- How to monitor indicators in Local Transport Plans and Annual Progress Reports – 2005 Update (Department for Transport, 2005)	8
Total numbers of indicators	**233**

Table 3. Ranking for the preliminary 20 best performing indicators (Castillo and Pitfield, 2010)

Rank	Indicator
1	Motorised traffic volume
2	Number of cycling trips
3	Vulnerable road user accidents
4	Local air pollutants
5	Modal share of public transport
6	Social/External cost of transport
7	Quality of public transport
8	Availability of key services locally
9	Total number of killed or seriously injured (in road accidents)
10	CO2 emissions from transport
11	Public awareness of transport sustainability issues
12	Percentage of freight transported by road
13	Length of cycling and walking paths
14	Access to public transport
15	Percent of population affected by high traffic noise levels
16	Energy consumption by the road transport sector
17	Number of crimes committed on or while waiting for public transport
18	Total number of road motor vehicles
19	Transport related wastes
20	Public participation in transport planning

5 EVALUATION CRITERIA

As it mentioned before, user perception and attitudes are an essential principle of the success of sustainability. It is important for those who affected by the concept – end-users – as it important for those who can affect sustainable decisions (Castillo and Pitfield, 2010). However, in order to address the end users attitudes, a numeric weight of important are required for each indicators by using multi-criteria decision analysis applications (MCDA).

Although there are numerous of MCDA techniques used in different contexts, many writing argued the accuracy of these techniques (Ball and Srinivasan, 1994; Castillo and Pitfield, 2010). However, one MCDA technique – the analytic hirarichy process (AHP) – devised by (Saaty, 1980) overcomes these problems. The AHP attempts to resolve conflicts through a process of determining the relative importance of a set of activities or criteria. The major difference between the AHP and other MCDM is that the AHP enables the systematic structuring of any complex multiplayer, multidimensional problem (Ball and Srinivasan, 1994).

5.1 AHP chart

The AHP chart is structured in two main levels; the first level is divided into five objectives based on the PROSPECTS project by (May et al, 2001) as; liveable streets and neighbourhoods, protection of the environment, equity and social inclusion, health and safety, and efficient economics. While the second level of the AHP chart contains the top 20 indicators of sustainable transport in the UK context. Those indicators have been introduced in the ELASTIC framework by Castillo and Pitfield (2010). AHP is constructed in Figure 1. In which each objective have a set of four different indicators.

However, in order to evaluate the users' perception and attitudes towards sustainable transport indicators, this paper has used a questionnaire-based survey in different locations – city centre, periphery, and rural areas – for Belfast. This survey aims to; first, identifies the most desirable objectives of sustainable transport defined by users. Second, it defines a hierarchy evaluation for all sustainable transport indicators from users' perspectives in different contexts. The participants were selected randomly in the mentioned above locations.

The data collected in the survey have been prossessed by using Microsoft Excel. First, all respondentes have been inputed in an excelsheet, then both arithemtic and geometric means have been calculated. Second, all geometric means have been normalised and used for the AHP final equations. Finally, AHP calculation have been generated using a custom formated sheet on Excel. Finally, the local and global means have been intoruced and analysed in the follwoing sections.

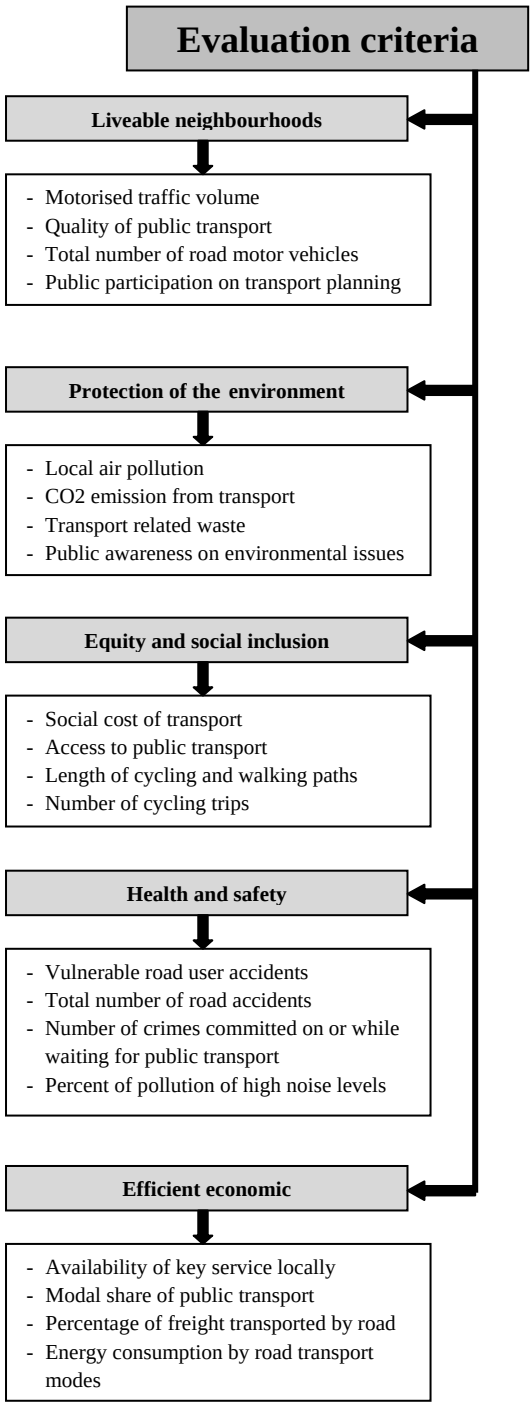

Figure 1. AHP chart

In order to assess the overall sustainability in the transport system,
Which of these objectives would you think more important

	9	*7*	*5*	*3*	*1*	*3*	*5*	*7*	*9*	
Liveable neighbourhoods	☐	☐	☐	☐	☐	☐	☐	☐	☐	Protection of the environment

Figure 2. Objective pair wise comparison

Table 4. AHP Standard scoring method (Saaty, 1996)

Intensity of Importance	Definition
1	Equal importance
3	Slightly more importance of one over the other
5	Moderate importance of one over the other
7	Strong importance of one over the other
9	Absolute importance of one over the other
2,4,6,8	Intermediate values between the two adjacent judgements

5.2 Survey 1, objectives weighting

The first survey was conducted by printed questionnaire distributed for both public transport and car users in different areas in Belfast city (city centre, periphery, and rural). In order to validate the data for AHP application, the participant were asked to make pair wise comparison for sustainable transport objectives based on AHP Standard scoring scale which is shown in Table 4. An example of the distributed questionnaire used for the first survey is illustrated in Figure 2.

5.3 Survey 2, indicators weighting

The second survey was conducted by the same methods as the first one. The participants were asked to compare between five sets of sustainable transport indicators. Each set (evaluation criteria) contains a group of four indicators – illustrated in the AHP chart – in which pair wise comparisons between these four indicators were generated. This process has been used for all the five sets in order to identify the weighting of each indicator. An example of the distributed questionnaire used for the second survey is illustrated in Figure 3.

6 RESULTS

In the survey 100 questionnaires have been distributed during July 2010 (50 city centre & inner ring, 25 periphery areas, 25 rural areas) only 70 have responded and 54 questionnaires are valid and used in the AHP model (25 city centre & inner ring, 18 periphery areas, 11 rural areas). The survey have ensured a balance of public transport users and car users, taking into account a mix of ages from 25 to 75 and a balance between male and female participants. All respondents' categories are illustrated in Table 5.

Table 5. Respondents' categories

Age Group	Public transport user		Car user		Total
	Male	Female	Male	Female	
25-34	5	4	6	3	**18**
35-44	3	4	4	1	**12**
45-54	2	3	5	3	**13**
55-75	3	2	2	5	**12**
Total	**13**	**13**	**17**	**12**	**55**

6.1 Evaluation criteria weighting

The results from the first questionnaire indicates that liveable streets and neighbourhoods are the most important criteria from the people perspectives with the global means of 0.3268 out of 1, following by protection of the environment (0.23), health and safety (0.1937), equity and social inclusion (0.1658), and support of vibrant and efficient economy (0.0781) with the consistency ration (CR) of (0.056). All results from the first survey are illustrated in Figure 4.

In order to assess the overall sustainability in the transport system,
Which of these indicators would you think more important

Liveable neighbourhoods										
	9	*7*	*5*	*3*	*1*	*3*	*5*	*7*	*9*	
Motorised traffic volume	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality of public transport
Motorised traffic volume	☐	☐	☐	☐	☐	☐	☐	☐	☐	Total number of road motor vehicles
Motorised traffic volume	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public participation on transport planning
Quality of public transport	☐	☐	☐	☐	☐	☐	☐	☐	☐	Total number of road motor vehicles
Quality of public transport	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public participation on transport planning
Total number of road motor vehicles	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public participation on transport planning

Figure 3. Indicators pair wise comparison

6.2 Sustainable transport indicators weighting

From the second survey, the results show that quality of public transport (global means = 0.3956) perceived as the most important indictor in the first group of liveable streets and neighbourhoods. While, local air pollution (0.4675), social cost of transport (0.4088), vulnerable road user accidents (0.4358), and availability of key services locally (0.5232) are the most important indicators of sustainable transport, each in protection of the environment, equity and social inclusion, health and safety, and support of vibrant and efficient economy groups in order. All second survey results are illustrated in Figures 5, 6, 7, 8, and 9.

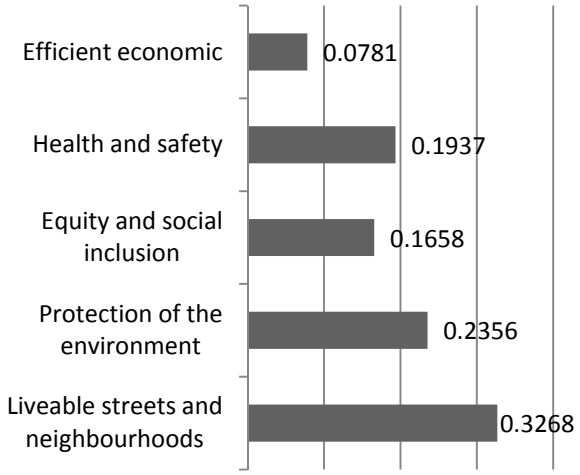

Figure 4. Evaluation criteria results
CR=0.056

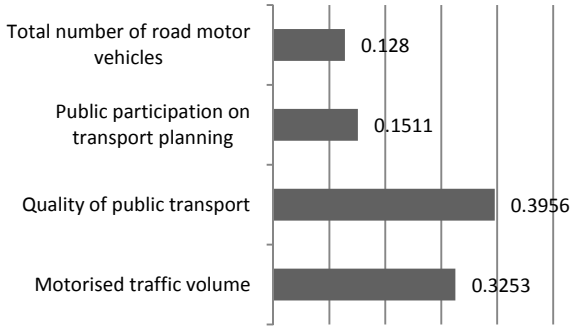

Figure 5. Liveable streets and neighbourhoods
CR= 0.071

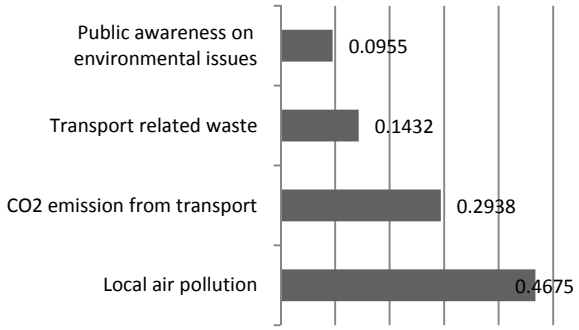

Figure 6. Protection of the environment
CR= 0.067

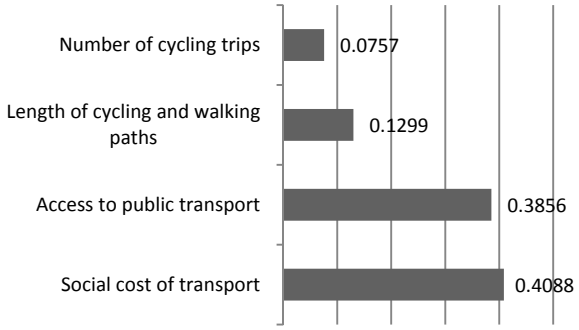

Figure 7. Equity and social inclusion
CR= 0.045

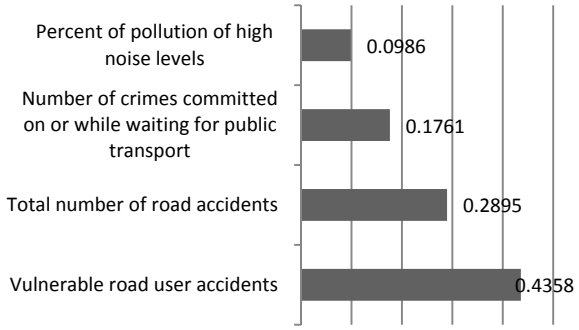

Figure 8. Health and safety
CR= 0.076

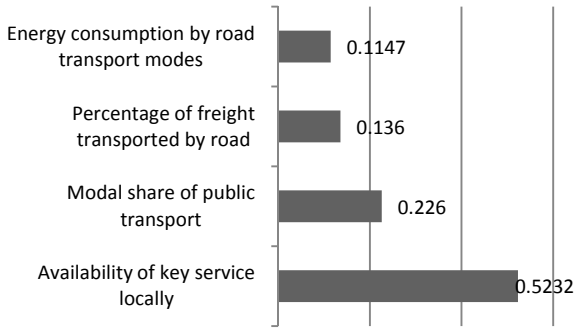

Figure 9. Efficient economic
CR= 0.099

However, the weighting of all sustainable transport indicators shows that quality of public transport is the most important indicator for sustainable transport system from the users perspectives with the absolute weight of (0.1293 out of 1), followed by local air pollution (0.1101) and motorised traffic volume (0.1063). While, energy consumption by road transport modes have been evaluated as the less important indicator in the sustainable transport system from the users' perspectives with absolute weight of (0.0090), which came slightly after percentage of freight transported by road (0.0106). The absolute weightings of sustainable transport indicators from user perspective are illustrated in Figure 10.

Meanwhile, the comparison between users' perception and stakeholders – which illustrated in Table 6 – shows that both users, academic, and planners sharing some priorities such as; motorised traffic volume, local air pollutants, and quality of public transport as the most important indicators sustainable transport systems. Meanwhile there was a variation in some indicators such as; number of cycling trips, modal share of public transport, and public participation in transport planning.

Table 6. Sustainable transport ranking "*users perception & stock holder perception*"

Stakeholders	Indicator	Users
1	Motorised traffic volume	**3**
2	Number of cycling trips	**18**
3	Vulnerable road user accidents	**4**
4	Local air pollutants	**2**
5	Modal share of public transport	**17**
6	Social/External cost of transport	**6**
7	Quality of public transport	**1**
8	Availability of key services locally	**11**
9	Total number of killed or seriously injured (in road accidents)	**12**
10	CO2 emissions from transport	**5**
11	Public awareness of transport sustainability issues	**14**
12	Percentage of freight transported by road	**19**
13	Length of cycling and walking paths	**15**
14	Access to public transport	**7**
15	Percent of population affected by high traffic noise levels	**16**
16	Energy consumption by the road transport sector	**20**
17	Number of crimes committed on or while waiting for public transport	**12**
18	Total number of road motor vehicles	**10**
19	Transport related wastes	**13**
20	Public participation in transport planning	**9**

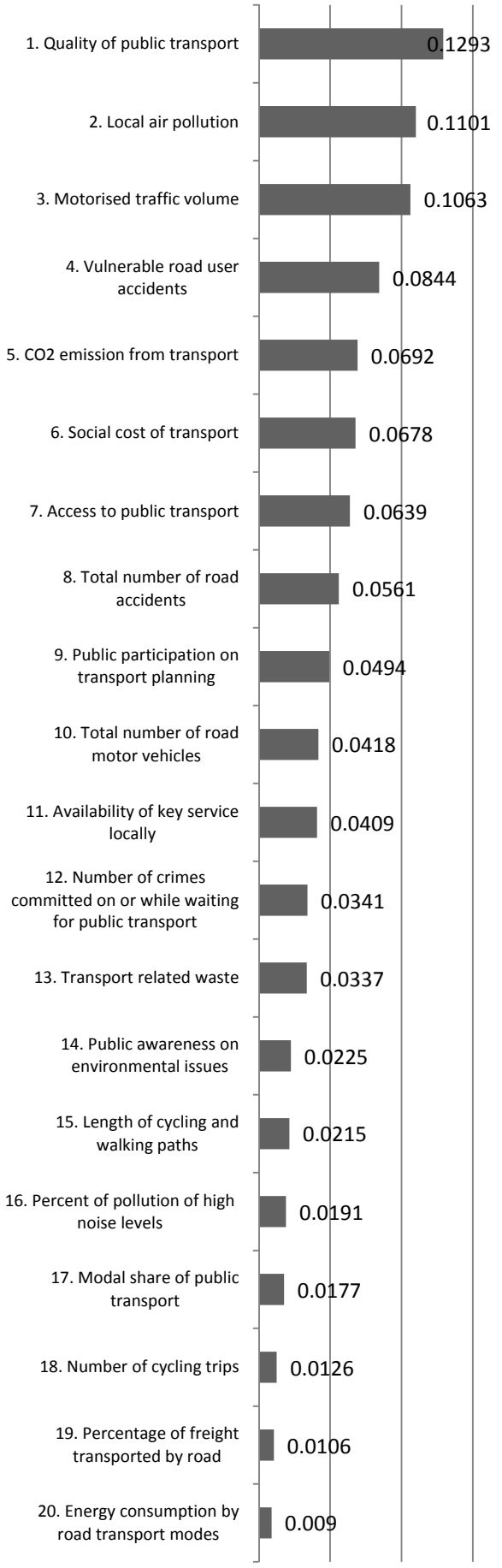

Figure 10. Sustainable transport indicators *"Absolute Weighting"*

7 CONCLUSION

Sustainability and its assessment in the context of transport is a challengeable process which incorporates many principles and participants. The key factor inside this process is to achieve the balance between policy makers' priorities, stakeholders' capabilities, and consumers' perceptions. The output and the success of sustainability in almost any context is highly depending on correlation between those three participants.

This paper addressed the users' perceptions and attitudes towards a sustainable transport system in Belfast. The paper provided a broader context in which both policy makers and stakeholders can visualise the whole picture of sustainable transport from different perspectives. However, it may be argued that quality of public transport is the key factor of sustainable transport chain, but with the massive effect and the multidimensionality of the public transport on the triple bottom life concept – environment, economic, and social – it is unsurprising to be perceived as the key factor of the sustainable transport form users' perceptions.

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IRISH TRANSPORT POLICY AND SUSTAINABILITY: DELIVERING A GREENER TRANSPORT NETWORK?

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ABSTRACT

The challenge facing policy makers today is to develop sustainable transport policies, whilst maintaining the balance between environmental and economic issues (Banister et al, 2000). The use of private motor vehicles for journeys such as commuting to work must be examined when creating solutions to decrease $C0_2$ emissions in-line with the Kyoto Protocol. Private motor vehicle ownership has risen by 146.2% over the twenty-year period from 1986 to 2006, which directly co-relates with the increase of 148.4% in number of motor vehicles used in the commute to work (Central Statistics Office, 2006).

This paper investigates reasons behind this increase, suggesting that failure by Irish governments over the last four decades to give sufficient importance to transport policy led to a lack of cohesion between government departments and agencies as to the responsibility for transport issues (Meldon, 1991, Department of Communications, 1985). This paper also looks at commuters' attitudes towards modal choice, transport policy, planning and infrastructure by analysing data gained through interviews carried out with commuters who travel by privately owned motor vehicles. The paper will conclude by looking at current Irish transport policy to examine whether policy makers are answering these challenges of achieving a sustainable transport system for the future.

Keywords: Transport Policy, Private car-use, Sustainability

1 INTRODUCTION: THE NEED FOR CHANGE

> "*One of the great challenges facing policy-makers at the start of the 21st century is to reconcile the different priorities between economic development and environment, whilst at the same time recognising the different social priorities and the distributional consequences of decisions. Transport offers us the best example of the complexity of these choices*". (P.1, European Transport Policy and Sustainable Mobility, David Banister et al, 2000)

International public awareness of global warming is increasing, leading to pressure on governments to guide the way towards sustainability. Targets for the reduction of carbon dioxide emissions set during the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, as well as the ratification of the Kyoto Protocol have turned this awareness into an acceptance that a change is required.

It is understood that transportation is the '*largest end-use of energy in developed countries and the fastest growing one in most developing countries*' (United Nations, 2009). Transport also contributes to noise and air pollution, congestion and health issues. In Ireland the transport sector accounts for 43% of final energy demand, creating 36% of energy related $C0_2$ emissions (Howley et al, 2009). Reducing the need to travel by improving development patterns through planning and land-use policies, encouraging alternatives to private motorised travel by favouring high-occupancy public transport modes, and efficiently and well maintained transport infrastructure are all advised.

Banister et al (2000) states that, as the developed world's largest population centre, Europe is in a unique position, and can lead the way in developing and promoting sustainable transport policies. European countries must work together in forming transport policies, as the Kyoto targets set are an average for fifteen EU countries. The United Nations Framework Convention on Climate Change (UNFCCC) affirms that emission level targets are set at 8% overall reduction of greenhouse gases for the EU15 (members of the EU in 1990) along with

Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Romania, Slovakia, Slovenia (member states since 2004 or 2007), Liechtenstein, Monaco, and Switzerland (non EU member states) (United Nations Framework Convention on Climate Change). The target levels set for Ireland limits emission growth to 13% above 1990 levels. Currently Ireland is at 23% above these base levels, although targets are expected to be met due to the purchase of credits from other EU countries (EPA, 2010).

2 PAST TRANSPORT POLICIES

Current European transport trends are recognised as being unsustainable (Banister et al, 2000). Bradley (1991) examines the fact that even though fuel efficiency and emissions reduction has improved, the consumption of fuel is being counter balanced by escalating traffic volumes. Policy makers in the transport sector must now deal with these issues, while still providing solutions to mobility problems and travel needs.

The impact of transport on the environment and ecological conditions is a relatively new phenomenon. Even so, it is now widely documented (Vigar, 2002, Banister et al, 2000, Whitelegg, 1993), and will not be discussed in great detail in this paper. It is suffice to say that, in terms of resources used, travel by private vehicle is considered to be more damaging to the environment than any other mode. Society has become dependent on cars to travel for work, leisure, shopping and socialising, with the car becoming an essential tool in every day life (Wickham, 2004). The need for more resourceful transport systems is, therefore, vital for access to the work place, places of education and other basic services. It is this that has led to an increase in pressure for policy changes within the transport sector.

In the past, policies have tended to be divided, solving one problem at a time, such as providing local solutions to bottlenecks, rather than focussing on the 'transport system as a whole across regions, sectors and modes' (Banister et al, 2000). It is this 'Just-In-Time' practice that has led to countries not looking at the transport system as a single, important entity. It is thought that this type of trend-based analysis does nothing to mitigate the steady increase in travel. Therefore, simply increasing road capacity to match the increase in forecasted demand, as the frequently used 'predict and provide' policies implemented tried to achieve, will not improve the mounting congestion problems, as more roads will be filled by the increasing volumes of vehicles (Vigar, 2002, Bradley, 1991). Bradley states that '*what is therefore needed is a sustainable transportation policy which puts protections of the urban environment (both physical and biological) as its goal and not simply relieving congestion*'.

Ridley (1991) and Barrett (1990) both discuss that the 'predict and provide' approach used by governments has seen policy aimed at mobility rather than accessibility, the answer usually being to build more roads to cope with the increasing number of privately owned motor vehicles. Instead, it is advised that attitudes to transport must be reassessed and that demand management will become more relevant in policy decisions. Barrett (1990) suggests that it is better to maximize the existing road space by proper management and coordination, as an investment approach has dominated a management approach to solving congestion. The relation between land-use and transport should be treated more significantly, as the level of travel demand can be greatly affected by better control of land-use.

O'Connell (1991) also discusses this issue, citing the EC Green Paper on the Urban Environment (1990), which states that '*transportation decisions are taken in an ad-hoc response to demand*' and are in no way related to any long term strategy to land-use planning or environmental concerns. The Green Paper recommends that cities stop land-use zoning and instead create mixed areas, therefore reducing demand for travel between amenities. However, O'Connell argues that due to the well-established land structure found in Dublin, this type of policy on land-use would offer little solution. Instead, the answer may be to redistribute modal balance by encouraging a shift from private car to public transport.

3 WHY IS CONGESTION SO BAD?

The phenomenon of urban sprawl has been talked about by many over the last twenty to thirty-years in relation to transport problems (Banister et al, 2000, Bradley, 1991, Department of Communications, 1985). Though every city is unique, The Department of Communications (1985) suggested that traffic problems are common in

nature, with the growth of population tending to disperse outwards. Banister et al (2000) discusses the fact that cities have become fragmented, with the development of large, low-density suburbs, leading to an increase in journey distance and length between home and work, schools, hospitals, shops and relatives and friends, the affect of which is most acute at peak commuting hours. It was suggested back as far as the mid-eighties that commuting from suburbs tends to be cars based due to the lack of public transport alternatives (Department of Communications, 1985). It is believed that to help reduce the amount of private cars on the road, the need for travel must be reduced. Banister et al (2000) and Bradley (1991) both suggest that transport and land-use policies must be linked to help reduce the spatial division that has occurred, with the development of new road plans being in accordance with land-use plans. This sub-urbanisation has led to the need for combined transport, land-use and environmental policies.

The lack of integration in Ireland is discussed by Meldon (1991). Two main reports, commonly known as the *Myles Wright Report* (1967) on land-use strategy and the *Dublin Transportation Study* (1971) on transportation planning dominated the period up until 1991. Myles Wright recommended a new settlement strategy for the Dublin area, with the development of four new towns, Tallaght, Clondalkin, Lucan and Blanchardstown, each being self sufficient with employment facilities, education centres and other amenities, the aim of which was to ease traffic congestion in the city centre. A good road network was planned, linking each town centre, with significant public transport networks. However, the reality was somewhat different; Myles Wright's hope for self-sufficient towns fell apart due to shops, schools, college and hospital all coming after the construction of residential areas. The fast population growth in these areas led to mass commuting, while the recommendations made by the Dublin Transportation Study '*still appear on each successive development plan as either 5-year or longer term objectives*' (Meldon, 1991). This gives a clear example of the gap between planning and reality. This researcher carried out a travel survey and in-depth interviews with employees working in the Blanchardstown area, one of the above named newly developed towns, in order to ascertain reasons behind commuting to work by privately owned vehicles and attitudes towards modal change to more sustainable modes of travel.

It is not only urban sprawl that has contributed to the increase in traffic congestion. Perry (1991) and O'Connell (1991) both discuss the attractiveness of independent travel; cheap, direct, comfortable and fast. '*The private car still remains a 'macho' image, being an essential element of material display and comparison*' (O'Connell, 1991). This attitude towards the private car must be examined, and alternatives that are just as attractive must be found and supplied. Irelands economic success has also attributed as a factor in the increasing volumes of the private car (McKinsey International Inc., 1980). However, despite Ireland's new found wealth, the 1987 European Conference of Ministers of Transport (ECMT) claimed that Ireland had spent the lowest GDP share on transport infrastructure; only 0.6% compared to the European average of 1.5% (Barrett, 1990).

4 THE DIFFICULTIES FACING POLICY MAKERS.

Vigar (2002) discusses the difficult choices local and national governments face in making transport policy decisions, due to the inter relationships between movement, economic growth and social justice. The need for a change in transport policy across Europe has been discussed for some time (Masser et al, 1992, as cited in Vigar, 2002). Banister et al (2000) claim that even though it is now widely accepted that current transport trends in Europe are unsustainable, there is little being done to put in place policy changes that will actually rectify these issues. However, it is also suggested that transport policy-makers are in a difficult situation, due to having to satisfy both environmental and economic issues.

Another problem facing policy makers is the reality that democratic governments do not like to implement measures that are unpopular with voters, as discussed by Bansiter et al (2000) and Vigar (2002). '*Transport policy is socially constructed in that what constitutes a 'problem', and the means used to address that problem, is a matter of political judgement*' (Vigar, 2002). This leads to many policies sitting on shelves, waiting for public opinion and attitudes to change before they can be successfully implemented. For the policies to be successful, the development and implementation requires consultation and co-operation from the

actual individuals, organisations and communities who will be asked to change their attitudes and behavioural patterns (). For this reason, it was considered important for this research that employees who drove to work by car were asked during in-depth interviews what action would encourage them to change to a more sustainable mode of travel.

5 TRANSPORT POLICY IN IRELAND

In Ireland there is a belief that the transport sector has been left stranded between state Departments and government agencies, and transport policy and investment has been neglected (National Economic Social Council, 1978, Department of Communications, 1985, Perry, 1991). It was not until recently that the Irish Government viewed transport as crucial, giving sole responsibility for all transport issues to one State Department, establishing the Department of Transport (DoT) in 2002. However, it was only in August 2007 that the Department of Environment, Heritage and Local Government (DoEHLG) handed over certain financial roles to the DoT for such areas as annual resurfacing budgets for local authorities.

This was despite the fact that back as far as 1980, this had been recommended in a report on Irish transport policy, commissioned by the National Economic and Social Council (NESC). In this report it was made clear that the need for a comprehensive transport policy was of great importance. The study advised that '*the transport problem in Ireland is no longer one of information, so much as of decisive action*' (NESC, 1980). The main issues raised in this report were organisational, such as the need for a State Department with sole accountability for transport issues, to replace the then current situation where transport was divided between the Department of Environment and the Department of Tourism and Transport. Also suggested was the need for a Transport Authority for the Greater Dublin Area, to supersede the State Departments, five Local Authorities and the state sponsored bodies such as Coras Iompair Eireann (CIE), who all had responsibility for particular sections of transport within the region.

This report went on to state that one of the main '*objectives of transport policy should be to make transport as widely available as possible*' (NESC, 1980). It found that, even then, the car was the dominant mode of transport, leaving the growth of public transport use static. The policy issues suggested were aimed towards increasing public transport use, by investment in rail facilities, regulation of traffic and parking, an increase in other traffic management issues such as priority bus lanes, particularly in the Dublin region, and subsidising public transport.

This echoed the advisory report by An Foras Forbatha (1971), who almost 10-years earlier had warned that '*major decisions regarding transportation and the future of Dublin should be made as a matter of urgency*'. This report found that, for example, the increase in motor vehicles since 1900 had not been mirrored by changes in infrastructure, as shown by the fact that there was not one new crossing of the River Liffey, and very few changes in the canal crossings. Again, recommendations were made in an effort to help reduce car use in the ever-growing congested streets of Dublin, including high-speed bus routes and an underground system linking the rail networks.

The Dublin Transportation Study Final Report (Steer Davies Gleave, 1991) found that the reason behind the failure to implement any recommendation made by the numerous major transport studies in Ireland between 1971 and 1980 as discussed above, is that not one of these reports were adopted as Government Policy. Indeed, Michael Walsh discussed during his conference reflections at the 1991 *Transport in Dublin: Policy and Practice,* that transport conferences in Dublin gave a sense of "de ja vu"; that is the same speakers, talking about the same issues, whilst the same problems persist, with no real urgency to act to solve them.

6 CURRENT TRANSPORT TRENDS IN IRELAND

The concern for the environmental impacts of transport relates to the volume of motor vehicle use. The growth in the use of the private car, and subsequent decrease in public transport use must be looked at when coming up with solutions to reduce carbon dioxide emissions. A Department of Communications Green Paper on Transport Policy (1985) stated that road transport was the predominant mode of transport in Ireland. The

Green Paper also advised that '*every person in Ireland has transport needs of one kind or another*', and due to the ever changing nature of this transport demand, the supply of transport should adjust accordingly in order to adequately meet the needs of the travelling public.

The most recent available statistics are from 2006 and 2007, and are taken from *Ireland North and South: A Statistical Profile, 2008 Edition* (NISRA & CSO, 2008), *Transport 2008* (CSO, 2009a) and the *Statistical Yearbook of Ireland, 2009* (CSO, 2009b). In the ten years from 1997 to 2007, car ownership in Ireland grew by 66.0%, from 1.13million to 1.88million cars registered. The use of private car as a mode of transport to travel to work has increased dramatically, leading to extremely high levels of congestion. The statistics indicate that, in 2006, the peak period traffic is being affected by 71.08% of the 1.892 million Irish work-force that travel to and from work by privately owned vehicles, including motorcycles, lorry's and vans.

The statistics also show that people are now living further from their place of work. The distance travelled to work within the state in 2006 was 15.19km, whilst in Dublin County and city the travel distance was only 10.81km. However, the average time taken to travel to work in the state was 29.6 minutes, whilst in Dublin it was 34.6 minutes. This shows that, even though the average commuter distance in Dublin is 28.8% less than the average national commuter distance, the time taken to travel this distance is 17.0% higher than the average national commuter time. The Dublin area has been described as a '*city in crisis'* (Steer Davies Gleave, 1991), and it can be suggested that one of the reasons for this is the lack of infrastructure Dublin has had in the past.

These statistics show that there is a distinct need for the Irish government to react quickly and efficiently to help reduce the amount of privately owned cars on the roads. It is also clear that there are a large number of people travelling to work in privately owned vehicles, which must be reduced by providing alternatives and encouraging adults to use these different modes of transportation. It is these changes that has now made it vital that transport policies are designed and implemented to contribute to sustainable development by not only slowing down this growth, but by reversing it. This can be achieved by facilitating access to alternative modes of transport, as well as reducing the need for travel at all.

7 CURRENT IRISH TRANSPORT POLICY

The Statement of Strategy 2005-2007 (Department of Transport, 2005a) stated that these aims would be achieved by integrating land-use and transport policies. This statement was the first half of a 5-year, €10.2 billion investment plan from 2005-2009 aimed at the effective delivery of transport policies. It acknowledges the fact that *'investment in transport infrastructure requires long lead in times for planning, design and consultation*'. The mission statement was developed from the mandate given in the Agreed Programme for Government, which is '*to implement an integrated transport policy'*. It was clearly stated from the outset that the government once again recognised the problem areas, but also seemed set on solving them.

The strategy was split into five high level goals, each with their own guiding principles, describing the way in which each goal will be achieved. Of importance to this paper is the goal of integration, the aim of which is to '*ensure an integrated approach to the development and delivery of transport policy…covering all modes of transport and underpinning the development of an integrated transport system and by integration of transport policies with other Government policies, particularly sustainable development*'.

As already mentioned, the goal of integration is of prime importance to this paper. The aim of the Irish Government is to allow people the option of '*moving seamlessly from mode to mode*', and to '*enhance the overall attractiveness of the network*' to the end-user. This is to be achieved by integrating fares, ticketing, timetables and general information. Also, as mentioned above, in order to reduce the number of private car use to and from work, there is a need to encourage modal shift to tackle congestion. '*A mix of transport policies is needed to help alleviate'* the impacts of congestion. The Department of Transport has recognised that it must work along with other relevant sectors and Government Departments to '*develop a coherent policy framework to address all modes and underpin the development of an integrated transport system*', as well as integrating transport policies with other Government policies,

particularly sustainable development and spatial and land-use policies. The Statement of Strategy outlines strategies and outputs for achieving the objective of integration and sustainability.

8 TRANSPORT 21

Part of the Department of Transport's way of achieving its goal of integration is to put out a 10-year transport investment plan. In November 2005 Ireland saw the launch of the governments €34.4billion new transport investment framework entitled *Transport 21*, which will see €9.4million invested every day for the next 10 years in Irish transport (Department of Transport, 2005b). Investment in transport infrastructure is required to ensure the effective delivery of transport policies aimed at overcoming '*existing delays, bottlenecks and congestion and to provide alternative choice by alternative modes of transport*' (Department of Transport, 2005a).

Transport 21 is the framework through which the transport system in Ireland will be developed, and aims to increase accessibility, ensure sustainability, expand capacity, increase use and enhance quality. Transport 21 also forms the 'cornerstone' of the Governments aims at achieving a sustainable transport network. A record amount of €16 billion is to be invested in public transport, in order to encourage modal shift by providing alternatives to the private car.

The third annual progress report for Transport 21 was published in 2008 (Transport 21 Division, 2008), and states that, in 2008 €3 billion was spent in total on Transport 21 projects. €890 million of which was spent on public transport, equating to approximately 29.5% of 2008 total expenditure. This included planning and preparation of LUAS and Metro links to Dublin West areas, improved Quality Bus Corridors and preparing for the introduction of an integrating ticketing system for the Greater Dublin Area. A very small 0.5% was spent on regional airports, leaving the majority, 70%, spent on the National road network.

9 SMARTER TRAVEL

In 2009 a new Transport Policy for Ireland was introduced, entitled Smarter Travel: A Sustainable Future, outlining strategies for the 2009 – 2020 period, the aim of which is to '*reverse current unsustainable transport and travel patterns*' (Department of Transport, 2009). In this document, An Taoiseach Brian Cowan states that it is not only infrastructure that must be improved, but also mindsets, in order that '*our institutions and individual citizens realise the benefits from altering their travel behaviour'*. There appears to be a realisation that public consultation is necessary and that a change in personal behaviour is necessary in helping to achieve a sustainable transport system by 2020. However, the aims set out in this document mirror those as stated in Transport 21 and the Statement of Strategy 2005 – 2007, verifying the sense of "de ja vu" discussed by Michael Walsh in 1991. In spite of this, this researcher believes that with more public consultation, which has now been prioritised by the government, this may now allow for more successful design and implementation of these transport policies.

10 RESEARCH RESULTS

Part of this research consisted of carrying out a preliminary travel survey with employees in a large worldwide computer company, based in Blanchardstown, Dublin 15. This survey was carried out in early 2004, and showed that 76% of employees travelled to work by privately owned motor vehicles, which is above the national average of 71%, as described above. The average travel time was 27.6 minutes to work and 31.2 minutes home from work, with the average distance travelled being 6.69km. These figures are both significantly below the 2006 national averages, as described above.

While statistics such as those discussed above are useful in showing the proportion each mode of transport accounts for on the journey to and from work, it is very important to recognise that travel is more complex than implied in such reports. Although some journeys to work do involve a simple outward and return journey, many do not, and there is little information detailing commuters daily travel behaviour. Since the introduction of Transport 21 and the large amounts of money being invested to increase infrastructure around Dublin, with the LUAS, increase in bus corridors and increased capacity on both bus and rail networks, there has still been a significant increase in commuters who travel to work by privately owned motorised vehicles; 19.3% increase over the period

2001 to 2006 (CSO, 2007). Therefore it is clear that there is a need to investigate this phenomena further to try to understand in greater depth the attitudes of these drivers, and to gain knowledge that may help in producing a more successful method of reducing the number of car commuters in the Dublin Area that policy makers can use effectively.

In the past, transport has been seen as a problem for engineers to solve. However, as discussed by Ridley (1991), it is becoming increasingly apparent that no matter how much new infrastructure is put in place, transport engineers must take into account human behaviour and psychology to help understand the material that is being dealt with; human beings. As discussed previously, there is a need to look at the traditional problem of congestion from a new stance, recognising that it is not always appropriate to mitigate the steady increase in car use by looking merely at trend-based analysis, but also to acknowledge that this may require changes in user behaviour. In order to look at this in more depth, travel behaviour and public attitudes must be explored.

Therefore, the main stage of this research consisted of in-depth interviews with those survey respondents who drove to work in privately owned motor vehicles. Many issues were discussed in detail, such as reasons for modal choice, perceptions of infrastructure and public transport available in Dublin and attitudes towards using alternative modes. This paper outlines some of the preliminary findings from these interviews in relation to these three topics, in order to aid policy makers in understanding users behaviour more comprehensibly.

10.1 RReasons For Driving To Work And For Not Using Public Transport

Two of the initial questions posed in the interview were 'why do you drive to work?' and 'why do you not use public transport to travel to work?' The most frequent responses for travelling to work by car and not using public transport correspond with one another; that is time and speed, no direct public transport route and convenience.

The majority of respondents outlined that the reason behind driving to work was a matter of saving time, or getting to and from work faster than if using another mode of transport. This corresponds with the largest response given as to why public transport is not used; public transport is too slow or takes too long. Time saved travelling produced extra time at home, to spend with family or carrying out other personal activities.

The second most frequent response given as to the reason for driving to work is that there is no direct public transport route, which again is the second most recurrent response given as to why public transport is not used. The lack of direct routes is also linked to the time spent travelling to and from work, and the reason why it is believed that using public transport takes longer than driving. Many of the interviewees describe the fact that as there is no direct route, it requires them to first travel into the city centre on one route, then travel back out of town to the suburb of Blanchardstown on a second route, before changing to a third route to travel into the Ballycoolin Industrial Estate, where the company is located. It is believed that there is a lack of cross-town routes, and in general a lack of infrastructure servicing parts of the city. One interviewee describes this:

"The public transport options seem to go definitely from city centre out. There's no kind of cross-town options or anything like that…But there's nothing that runs from Rush, or Skerries, it's all like from there into town and then back out." (#10)

Even for those who accept that they live relatively close to work, there is still an impression that the lack of direct routes is a negative when choosing a mode to travel to work. The journey on public transport, therefore, not only takes longer, but is also seen to be extremely inconvenient, another frequently given response to both questions. Also, it is often mentioned that many of the routes around the Blanchardstown area travel in and out of the increasing number of housing estates that have been constructed over the years, causing the routes to take longer again. Therefore, the routes themselves are perceived to be highly inconvenient. The inconvenience of public transport correlates with the convenience of the car, and there are a large number of interviewees who state that this convenience in itself is a major consideration when choosing which mode of transport to use, even when alternatives are available.

Some responses go further in describing the exact reasons as to why the car is considered so convenient. One interviewee states that the car is convenient when dealing with the unpredictable Irish weather, and indeed the weather was a response given by a small minority of interviewees. Other responses given on the convenience of the car include the fact that it is direct, which corresponds with the indirect public transport. Freedom of the car was also a response given by a few interviewees, with one interviewee outlining that the convenience in having the car allows freedom to carry out other tasks on the way to and from work.

The third most frequent response given for the reason behind driving to work was distance; that is the interviewees perceived themselves to live too far from work to use an alternative mode. Further examination found that all of these respondents lived a distance of 13.6km or more from work, a distance accepted to be too far to either walk or cycle to work. The Institute of Highways and Transportation Guidelines for Providing for Journeys on Foot (2000) suggest that 2km is the maximum desirable distance that commuters will walk to work, although the distance acceptable for cycling to work caries between 5km and 8km (Sustrans, The Highland Council).

The majority of the responses to the question 'why don't you use public transport to travel to work' were negative towards public transport, with some of the less frequent responses being that public transport was dirty, inefficient, over crowded, too expensive, unreliable and uncomfortable. Timetable issues were also mentioned by a minority of interviewees, with the fact that services are infrequent being stated as the reason why public transport is not used more often.

Again, similar to reasons given for driving to work, two interviewees gave the response that they have a car and therefore will use it. Interviewee number 22 clearly stated that she learnt to drive and therefore bought a car and will use it to drive to work, even though she recognises that she only lives 2km from work and there is a direct bus route. Laziness was also a response given by one interviewee.

10.2 MModal Choice If Car Not Available

Another question in the area of modal choice was 'how would you travel to work if your car broke down?' This was to ascertain whether or not alternatives could in fact be utilised for the journey to and from work. A large number of responses continued to involve the use of privately owned vehicles, including getting a lift from a partner, getting a lift from a colleague or having a second car available, including making the owner of the second car use an alternative mode so that the interviewee could continue to drive to work:

"I would, eh, make my sister get the bus and I would take the car." (#3)

Those interviewees who had second cars available were probed further, and asked if there was no second car how would they travel to work, with further responses being ascertained from all of these respondents.

The joint most frequent response over all was that the interviewee could get a lift to work from a colleague, which would be car-pooling. The other most frequent response was that public transport could be used to travel to work. It was also found that a large minority could in fact walk or cycle to work if a car was not available to them.

Therefore it was found that there are alternative modes available to a large majority of car drivers interviewed, although two interviewees, #11 and #13 responded that they would have to take a day off work. Their only other option was to either get a taxi to work, or physically move house in order to get to work, until such a time that the car returned to working order. Taking these two respondents into account, it could be concluded that a large majority of those who drive to work could in fact find alternative means of travelling to work if required.

10.3 PPerception of Dublin's Public Transport Network

This section outlines the findings from the interviewees in relation to the perception of the public transport system in Dublin. The findings come from both answers to the direct question

'what is your perception of public transport in Dublin', as well as other responses given throughout the interview.

Negative Views of Dublin's Public Transport Network

The majority of responses to this topic were of a negative connotation, with every interviewee having at least one negative view of public transport in Dublin, and a significant number simply stating that it was "*poor*" (#19), "*atrocious*" (#2), "*appalling*" (#4) or worse. There was an extensive number of responses given, and many respondents had more than one negative view.

The majority of interviewees stated the public transport system in Dublin was worse than public transport systems in other countries, comparing it to countries such as the UK, France, Holland and the U.S. There were many items that were used to compare public transport systems, such as difference in fares and frequency of services. However the principal point of comparison was the lack of over all infrastructures in Dublin compared to other cities such as London, Newcastle, New York and San Francisco. It was suggested that the lack of infrastructure leads to a lack of integration and links between services, making it difficult to travel through Dublin.

Another employee discusses his frustration at the lack of infrastructure, describing the current number of transport systems that are available, yet referring to the fact that they do not link up or service the entire city:

"Cos I think it's all done in like bits and pieces. I can't understand why you have like, em, the DART, and then you have a bit of the LUAS somewhere, and you've nothing here, out here, and, well you've got a main train that goes through some places, and I can't understand why they couldn't have done it the way you see in other countries. I was over in Newcastle there last weekend and they have a metro that literally runs everywhere, all over the city, everywhere, to anywhere you want to go. It's brilliant, so clean, so convenient, and accurate and on time. I can't understand why we have a bit of this and a bit of that…Like, I gave you an example of Newcastle, which is just an urban city in England, which isn't even the capital, and the transport system is ten times better than here like." #8

This comparison links with two of the other responses given. The second most frequent response, where half the respondents stated that that there was a lack of infrastructure in Dublin, as well as a small minority who stated that there was a lack of integration between the existing services. The thoughts on lack of integration was primarily in relation to ticketing, with all who referred to integration discussing the benefits of a single ticketing system for all modes of public transport, including all buses, DART and LUAS routes.

There is, therefore, an overall strong belief that there is a lack of public transport options available in order to easily and efficiently travel around Dublin. However, a number of employees did reason that where the infrastructure did exist it was seen as a positive system. The principle positive response given was that the LUAS and DART are perceived to be good systems. The negative aspect is that they only serve part of the city, and few employees at Creative had any experience of using either system.

Again, another factor connected to the lack of infrastructure and links available via public transport is the third most frequent response given, which was in relation to inconvenient routes. As mentioned previously, this was a frequently given response as to why these commuters do not travel to work by public transport. The perception by many of the interviewees is that the existing public transport routes all start or end in the city centre, with no cross-city routes in operation. An inconvenient route was also described as one where a journey was elongated due to the route being overly indirect by having to service a greater area, with some interviewees stating that buses have to drive around numerous housing estates before reaching its destination, lengthening the route and therefore the time it takes to travel.

This links into another response, where a number of interviewees view the lack of infrastructure as bad planning, and state that there should have been more planning at development stage. It was mentioned by a number of interviewees that the increase in the number of housing estates was not mirrored by an increase in public transport networks, causing the existing services to cater for

larger areas and numbers, as referred to above. One interviewee believes that it is now too late to make the area of Dublin 15, where Blanchardstown is located, fully functional, but instead any newly implemented or constructed networks will simply be to stop congestion deteriorating further, rather than actually improving matters. He discusses the lack of any LUAS or DART system for west Dublin:

"They had a good opportunity to do the same thing, to do something with D15 because in '95, '96 this was still a very, like there was no such place as Clonea, Clonsilla was just a small village, the Blanchardstown centre wasn't built, Tyrellstown wasn't built, up near where I live, that wasn't built up either so they had a great opportunity to put either the M50 in, they had a great opportunity to put a rail link in, or at least make provision for a rail link, which they just didn't do. So I think any changes they do try and make now will be just treading water. Em, its just as bad, it'll get worse, or they'll do a few things, like as I say, you know, a few cosmetic changes, change the sequence of the lights, put in a few one-way systems round the Blanchardstown centre maybe, but it'll just be treading water really." #7

Another theme found in relation to negative perceptions of public transport was that of timing. As mentioned above, the lack of infrastructure is the primary perception of those interviewed. The lack of road infrastructure was also mentioned, with the fact that buses get caught in the same traffic congestion than private vehicles:

"I suspect it's probably because there's no dedicated transport channels for them to use so they're getting caught up in the same traffic that everybody else is getting caught up. And the bus lanes for example, certainly make a difference. But when you have bottlenecks every so often down the bus lanes you're basically just racing down to the next bottleneck every time and you have to rely on the good will of hassled commuters to let the bus out."#6

Therefore, it is clear to see that there is an overall feeling of frustration that there is a lack of public transport options and infrastructure allowing employees to access their workplace easily and effectively. This is despite the fact that, as far back as Myles Wright's 1967 report, there were recommendations made to assist the development of self-sufficient suburban town areas, including Blanchardstown, with good road network and significant public transport networks making employment centres and other amenities more accessible.

Positive Views of Dublin's Public Transport Network

In comparison, it was also found that a large majority of the interviewees had at least one positive or optimistic view of the public transport system. A small minority stated simply that it was "OK" or similar. However, these respondents acknowledged that they lived on or near a good route, mostly into the city centre. As discussed previously, the most frequent positive response towards public transport was in relation to the LUAS and DART systems, which are seen as good systems for those who can avail of them. Similarly, there is an awareness that there is a reliable means of travelling into the city centre. The fact that it is perceived that there is no orbital routes, and all public transport routes start or end in the city centre, was discussed above as a negative aspect for travelling around Dublin. However, it is clear that overall there was a considerably negative attitude towards the public transport network in Dublin.

10.4 AAternatives

Another aspect to the interviews was to ascertain whether or not those who drive to work would be willing to use an alternative mode to travel to work, and what would encourage them to do so. This is because it is believed that in order for government policy to be implemented successfully, those members of the public who will be affected must be consulted in order for changes to be accepted and put into practice (Vigar, 2002). Firstly, it was established through analysing the transcripts whether or not the respondents would be willing, under any circumstances, to use an alternative mode to travel to work. The majority or those being interviewed gave responses that indicated that they would be willing to change, however, there was a large minority who stated they would not be willing to use an alternative. The alternatives that were considered included all possible substitutes, from using public transport, car-pooling, cycling and walking:

This was then followed by further questions in relation to what specific actions would be required to induce the interviewees to change mode of transport. There was a wide range of responses, with all respondents except two gave more than one response. The single response given by these two respondents, #7 and #22, was that nothing would encourage them to change mode.

The most frequent responses given were in relation to improved infrastructure, direct public transport routes and an increase in the cost of driving. As discussed previously, the interviewees had a mostly negative perception of the public transport available throughout Dublin, with a significant number stating that there was a lack of infrastructure and integration between existing services, making it difficult to travel around Dublin. Responses included extended LUAS and DART lines or a metro style network that includes Blanchardstown on its route, as well as improved road surfaces, widths, cycle and bus lanes and improved pedestrian footpaths. In relation to direct bus routes, a significant number of respondents, just under half, stated that they would use public buses if there was a direct route, including a direct route to Blanchardstown shopping centre, which would still require a change to a second local bus to the industrial estate. The main negative aspect of indirect bus routes was the need to travel in and out of the city centre.

11 CONCULSION

It is quite clear, and has been for some time, that there is a need for integrated transport systems and the promotion of the use of non-motorised modes of transportation. With a view to providing safe, affordable and efficient transportation, increasing energy efficiency, reducing pollution, congestion and adverse health effects and limiting urban sprawl, '*national strategies, plans, policies and processes are crucial*'(United Nations, 1993).

As discussed, issues were being raised about traffic congestion in Dublin as far back as 1967, and recommendations were being made for long-term solutions. The reason that these recommendations were ignored time and time again is hard to understand, and Ireland, especially the Greater Dublin Area, is now paying the price for the lack of acceptance and leadership in needing to provide a better infrastructure.

In a way, the repetitive nature of transport strategies in Ireland over the last 30-years is not encouraging, as it shows a lack of conviction of Irish Government both past and present to actually commit and lead the way in sustainable mobility. The failure of past Governments to act promptly to recommendations made by industry experts, as well as poor funding and design of infrastructure, has led to the current crisis in Irish transport. The new aim in transport policy should be to reduce the amount of private car use by making public transport more attractive and efficient.

It is also crucial that the public be consulted during these periods of implementation, as it is the commuters who, as end users, will determine whether or not these policies will be successful in reducing the number of cars on the road. Only by understanding traveller behaviour more deeply will policy makers be able to effectively change attitudes towards transport and ensure a successful shift to more sustainable transport modes. As can be seen from the preliminary findings shown above, there is a wide range of responses given as to why these commuters drive to work, with every interviewee having negative attitudes towards the existing public transport network and infrastructure as a whole. Therefore, it is essential that these reasons be considered during the planning, designing and implementation of new policies.

It is also evident that for transport policy to be successful, policy makers from different governmental departments must work together by decreasing the distances being travelled, and reducing the need to travel at all. Again, it was discussed above that every interviewee lived more than 8.5miles from the work place, a distance accepted to be too far to either walk or cycle to work. Looking at current Irish transport policy, there appears to be a strong understanding of what is required to achieve this, and policies are indeed being put in place. However, the lack of policies in the past has led to the under investment in the transport sector, which in turn has led to the poor quality of transport infrastructure in place in Ireland up to 2005. Since the introduction of Transport 21, and its apparent success in delivering ahead of schedule, and within budget (Transport 21 Division, 2008), Ireland is heading towards a future with a

greener transport network. Whether this policy is successful enough to not only catch up with the deficit left by years of inept policy making, but to ensure a '*better quality of life for everyone, now and for generations to come*' (World Commission on Environment and Development, 1987), is yet to be seen.

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SMARTER TRAVEL IN SIX EUROPEAN CITIES - A PRECEDENT STUDY

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ABSTRACT

This precedent study details six European cities that portray leading best practice in the implementation of continuous and integral transport policy. This study describes the course of development of transport policy in each city, specifically seeking how each city achieved such high bicycle and public transport use. The six "Smarter Travel" cities concerned are Malmö in Sweden, Copenhagen and Odense in Denmark, Groningen and Delft in The Netherlands and Freiburg in Germany.

Keywords: Smarter Travel, Transport Policy, Cycling, Travel Behaviour Change

1 INTRODUCTION

"Smarter Travel - A Sustainable Transport Future" the new transport policy for Ireland was published in February of last year (2009). This policy was launched as a response to Ireland's ever increasing demand for road transport and details how a sustainable travel and transport system can be achieved in Ireland by 2020. In order to fully understand how this vision can be achieved in Irish cities such as Limerick, this study was carried out to investigate European experiences and the transferability of successful sustainable travel and transport policy. This study details six European cities that portray best practice in terms of continuous and integral transport policy, modal split for all journeys, especially bicycle mode share, land use planning, and car free initiatives.

The six cities chosen cities are Malmö in Sweden, Copenhagen and Odense in Denmark, Groningen and Delft in The Netherlands and Freiburg in Germany. Copenhagen and Groningen were chosen as both cities are famous for their bicycle mode share, in particular Copenhagen. Malmö and Odense were selected as both cities have engaged in recent campaigning for travel behaviour change towards more sustainable modes of transport, cycling in particular in Odense. And finally Freiburg and Delft were included in this precedent study as Freiburg is of similar size to Belfast City and Delft shares a similar population with Limerick City for comparative purposes.

Figure 1 and Figure 2 outline the modal split and population comparisons between Limerick and the chosen six European cities, respectively.

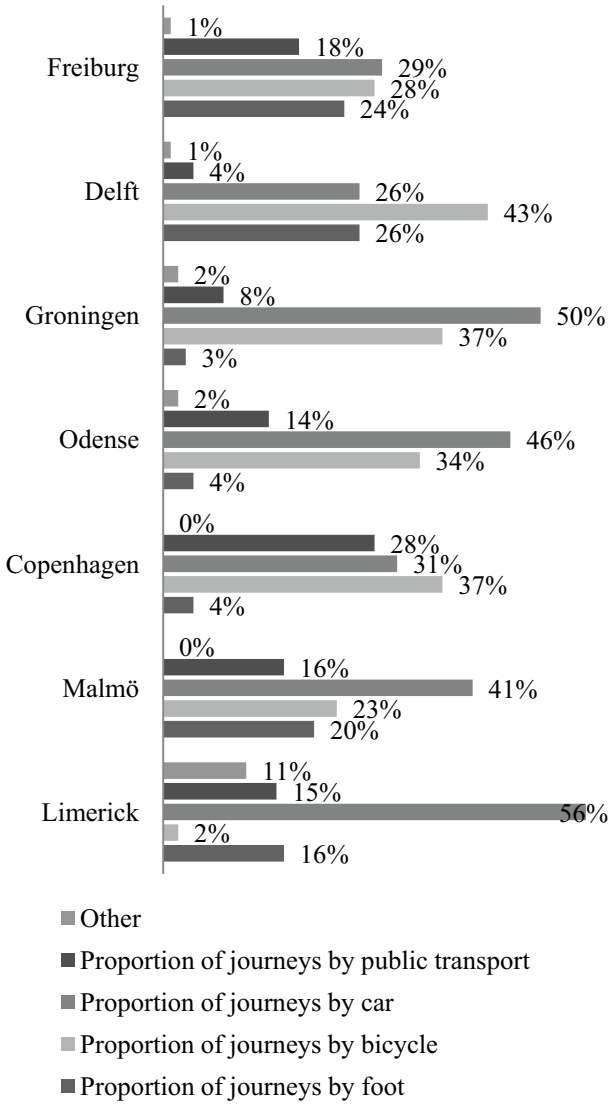

Figure 1. Modal Split Comparisons

(Source: Limerick 2006 Census; Malmö, Odense and Freiburg Urban Audit 2004; Copenhagen 2008 Bicycle Account; Groningen and Delft 2006 Dutch Bicycling Council)

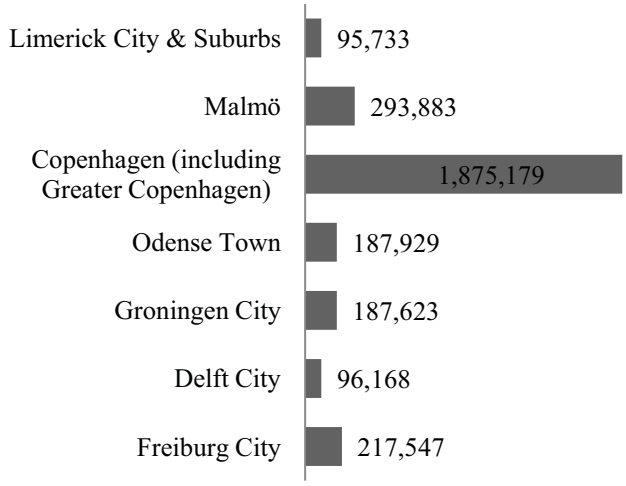

Figure 2. Population Comparisons

(Source: Limerick – www.limerickcity.ie; Malmö - www.malmo.se; Copenhagen - www.kk.dk; *Odense - www.odense.dk; Groningen and Delft - www.cbs.nl: and Freiburg - www.freiburg.de)*

2 MALMÖ

"Transportation and buildings account for the largest share of climate-changing impact. This means that we must mitigate climate change largely at the local level that we must work for the sustainable city. Municipalities must function as role-models on the climate issue"
Ilmar Reepalu, Mayor of Malmö 2008

2.1 Introduction

Malmö is Sweden's third largest city and has a population of 293,909, as of the 1st of January 2010. Malmö City is the capital of Skåne County located in southern Sweden. During the eighties and nineties Malmö underwent a period of economic recession and high unemployment. However, during the last decade Malmö has consciously reinvented itself as a sustainable multi-cultural European city of the future with major developments such as the opening of Malmö University. Malmö City actively works to facilitate the city's traffic, with a strong focus on public transport and non-motorized transport, especially the bicycle. There are 143,000 jobs in Malmö city and 55,000 people commute daily into the city to work. Figure 3 outlines Malmo's modal split for those commuting to work every day.

Malmö city incorporates approximately 420 kilometres of bicycle paths, containing more bicycle pathways than any other Swedish city, thus being known as "Sweden's Cycle City." In fact Malmö has five kilometres more than its sister-city Copenhagen, which is world famous for its bicycle culture. The City of Malmö (Malmö's city council) carries out a large-scale travel habits survey every five years, with the most recent survey having been carried out in 2008. In addition, the traffic is counted yearly at 140 traffic measure points across the city. From this, the movement of the traffic to and from different areas in Malmö is obtained.

The city's monitoring of the changes in the travel habits of its people has so far conveyed that cars are being used for shorter journeys less often. In addition, the number of journeys per person for 2008 and 2003 is on average the same. However, the number of car journeys fell from 52% of all journeys in 2003 to 41% in 2008. Conversely, the number of shorter journeys on foot and by bicycle increased, and for longer distances the number of train journeys also increased. This is in line with the increases in rail and bicycle traffic recorded in the entire region. Overall, the percentage of bicycle journeys rose from 20% to 23%, with the number of journeys on foot increasing from 14% to 20%. Train journeys also increased from 3% to 5%. The modal split for all journeys is outlined in Figure 3.

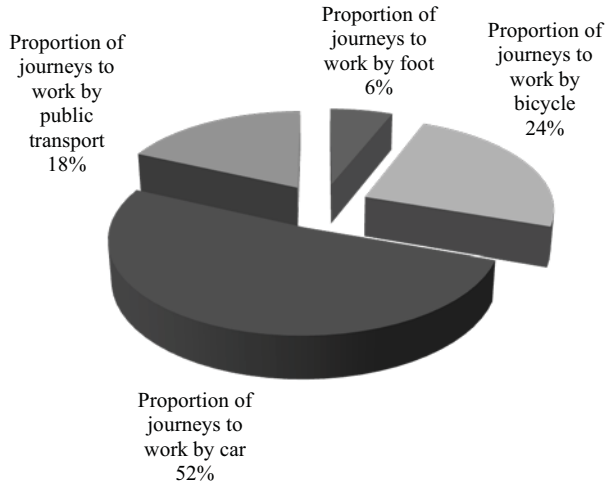

Figure 3. Malmö Modal Split

2.2 Cycling in Malmö

In 2008 cycling in Malmö increased by 11%; with approximately 30% of all transport journeys occurring via a bicycle. Malmö's high cycling rates can be attributed to the city councils continuous

investment in providing well connected and integrated cycle routes. An extensive cycling route runs through Malmö city from the southern part of the inner city to Universitetsholmen in the north. (Universitetsholmen is a small artificial island in Malmö harbour, surrounded by bays and channels, to the west of the train station). This route varies significantly in character. In the north, it runs past the old part of town before following the more fashionable streets of the city, and finally branching off eastwards to the city suburbs. Figure 4 below highlights the density of the cycle network of Malmö.

Malmö city continuously invests in improving its cycle routes and increasing its already impressive percentage of bicycle mode share. At present a variety of solutions are being tested along this stretch of cycle network already mentioned which runs through Malmö from the southern part of the inner city to Universitetsholmen in the north. For example, different types of lighting are being trialled along the route to improve visibility in the dark. Malmö city's aim is to make cycling faster, safer and more enjoyable. The innovations introduced along this route include rails at traffic lights which cyclists can rest against so that they do not need to put their feet down.



Figure 4. Malmö Cycle Network

(Source: Malmö Stad - Official website of City of Malmö. www.Malmö.se)

Large mirrors have also been erected at crossings to allow cyclists to see around corners where visibility would otherwise be poor. Air pumps have been installed at six locations around the city for cyclists who need to top up their air. (Similar pumps can be found in Odense in Denmark). The pumps can also be used for prams and wheelchairs. Tools have also been added to the three air pump stations along the cycle route, turning them into mini-service stations where cyclists can carry out their basic repairs.

"Cycling barometers" at different locations in the city automatically count and display passing cyclists which provide a visual indication of cycling levels in Malmö; showing how many people cycle in Malmö, encouraging and reminding cyclists that they are appreciated. Radar sensors have been fitted at 28 intersections in Malmö to detect approaching cyclists and automatically give them a green light at intersections, which are not already crowded by car traffic. At the junctions the lights turn green quickly in favour of the oncoming cyclists allowing cyclists to flow more smoothly in traffic. A free map is also available which portrays all of Malmö's cycle paths. The map is updated every year to show new cycle paths. The latest version is always available from the town hall and tourist information offices.

Skånetrafiken's (the regional public transportation authority) website includes an online bicycle journey planner which when one inputs their journey origin and destination, it then suggests the best route to take when cycling in Malmö. A time comparison for the same journey by bike, bus, and car is also provides, with cycling often coming out on top.



Figure 5. Malmö Bicycle Parking

(Source: Google Images)

2.3 Public Transport in Malmö

Skånetrafiken is the regional public transportation authority and operator in Skåne. Skånetrafiken was founded in 1999 when the two counties Kristianstads Iän and Malmö Iän were merged into one region. During this merger the two respective transport authorities were amalgamated. Presently, Skånetrafiken is a part of the regional government of Region Skåne. Within the city, Skånetrafiken's green city buses run frequently along lines and are entirely powered by biogas. A focus on modern, environmentally-friendly public transport means that passengers can find out departure times using their mobile phones and public transport is given priority at crossings, ensuring green, clean travel.

The Öresund train, which departs from Malmö every twenty minutes, also links Malmö with Copenhagen and the rest of Denmark. The Öresund Bridge (as seen in Figure 6) is a combined two-track rail and four-lane road bridge across the Öresund strait. It is the longest combined road and rail bridge in Europe and connects the two metropolitan areas of the Öresund Region: Malmö with Copenhagen. The international European Route E20 runs across the bridge and through the tunnel via the two lane motorway, as does the Öresund railway line. The Öresund Bridge has connected mainland Europe to Sweden and the rest of Scandinavia. The Öresund Bridge connects the two cities of Malmö and Copenhagen allowing the cities to better compete against other European cities. It also provides for the creation of diverse revenue streams and allows for more efficient resource utilisation. In addition, it encourages more collaboration between universities, research institutes, and corporations.

Approximately 29 million journeys are made on city buses in Malmö each year. Several policies and programs have attempted to make city buses an even more attractive choice. Such efforts include increasing the frequency of bus transportation, as well as providing for bus traffic lanes. Additionally, Skånetrafiken has installed digital real-time signs at almost 100 bus stops in Malmö so that travellers can see when exactly buses will arrive. One can also get real-time information via mobile phones using either mobile internet or a downloadable program. Having a mobile journey planner allows travellers to plan their journey while on the go.

Skånetrafiken's city bus services in Malmö are based around eight "trunk lines" which cover much of the city. City buses run so frequently on these lines that there is almost no need for a timetable. During the rush hour, most of these lines run almost every six minutes. Skånetrafiken has also drawn up a safety policy and installed cameras on all city buses for greater security onboard. Bus travellers in Malmö take priority in purely practical terms, the city's buses communicate electronically with traffic lights so that they get a green light more quickly than cars. And if the traffic light is about to turn red, buses are given a green light for a few moments longer.



Figure 6. The Öresund Bridge

2.4 Environmentally-Friendly Cars and the Transportation of Goods

Renewable biogas is produced in Malmö, and ethanol is available from many of the city's petrol stations. In Malmö, VA SYD (Waste and Sewerage Authority) collects organic waste such as leftover food from households and restaurants. The organic waste is then composted at the city's sewage works. This produces biogas, which is pumped into Malmö's biogas network, producing a total of 20 GWh each year (the equivalent of 2 million litres of petrol). This allows both buses and cars to run on renewable food waste, without producing fossil carbon dioxide emissions.

The City of Malmö and many of the city's organisations and businesses are investing in environmentally-friendly cars. Employees working for Malmö's city council receive the opportunity to join ecodriving training. The city councils own

fleet of vehicles already consists almost exclusively of environmentally-friendly cars and a large number of private companies have followed the councils lead. The city councils company vehicles are almost exclusively classified as environmentally-friendly cars, with many those using renewable fuels such as biogas and ethanol. A few are electric, and one even runs on hydrogen gas from wind power. In Malmö, driving an environmentally-friendly vehicle is both easier and cheaper. Malmö city has a low-emissions zone for HGVs. Within this zone only HGVs with modern engines are permitted. Those who drive environmentally-friendly cars made within the last three years can also apply for a special parking permit from the city council which entitles them to one hour's free parking.

Malmö Lastbilscentral (Malmö Lorry Centre) has also invested heavily in "heavy ecodriving" – economical driving for HGVs – enabling it to make an approximate saving of 15% on its fuel consumption. Some vehicles have also been fitted with onboard computers which can work out the fastest route and how much fuel will be used. In addition the company has seen a significant reduction in damaged goods since introducing these measures. The city council has also helped to set up an ordering system which connects food producers with restaurants and caterers via a website. Farmers can upload details of seasonal produce and restaurants can log on to order locally-grown, organic food which is then delivered on a pooled basis by biogas-powered lorries. Shorter journeys and less empty mileage help save both money and the environment.

2.5 Sustainable Urban Planning

Historically Kockums shipyard was located in Malmö's Western Harbour; today the area is home to Bo01 - Sweden's first climate neutral city district. The area is supplied completely by local renewable energy over the course of a year. Bo01 incorporates an eco-friendly transport system, with buses connecting Bo01 every 10 minutes. Bus stops feature real-time displays so passengers know when the next bus will arrive. Bicycles are common and the district features a carpool.

2.6 Changing Travel Attitudes and Behaviours

Since 2001, the Malmö's city council has been actively working on changing travel attitudes and behaviours. The ultimate goal is for more people choosing to walk, cycle, or use public transport, instead of using their cars. The fact that so many parents regularly drive their children to school has become a major problem, as in Ireland's towns and cities. The "Friendly Road to School" project aims to encourage parents of children attending the first few years of school to walk or cycle to school with them instead of driving them by car. Each metre walked by pupils on their way to school is converted into a footstep on a giant map of Europe at each of the participating schools. In this way, the project can be integrated into teaching and the children learn about the cities and countries which they "pass through."

Persuading companies to take more responsibility for business travel and employees' journeys to and from work is part of the work involved in changing travelling habits. Having held seminars and breakfast meetings on the subject, Malmö city council started to work with companies by offering help and advice in drawing up mobility plans including measures to change travelling habits. In the "Businesses on Bikes" project 53 companies replace ridiculously short car journeys with bicycle journeys.

2.7 Success in Malmö

Malmö's success has been down to the fact that the municipality, different businesses and people are willing and happy to work together to help make a better future for the city. In the Western Harbour, the municipality led the way and brought together house builders and the local energy company. They also involved people, asking them what they would want the Western Harbour to look like. The result is a place great for the city, great for the businesses that took part and great for the people. Furthermore it appears that Malmö city's success is also down to its strong and continuous integration with public transport. In December 2010 a new city tunnel will be opened to the public which will connect train travel north of the city to southern connection points. The "City Tunnel" will consist of 17 kilometres of railway and 6 kilometres of tunnel, generating the largest investment in public transport in Malmö's history.

3 COPENHAGEN

3.1 Introduction

Copenhagen is known internationally as a model bicycle friendly city. In Denmark taxes are used to invest in the country's energy and environmental future, creating new revenue opportunities. Denmark's citizens support investment that improves their environment and creates jobs. The result is short term energy savings and the lowest long term prices for energy. The people of Denmark accept that global climate change is real and create regional pride in people by pursuing a global mission.



Figure 7. The City of Copenhagen

The emphasis on public transport and bicycle commuting in Denmark and in fact throughout Scandinavia has emerged based on the following two values that Scandinavians possess:

1. Universal mobility – everyone regardless of their financial situation, age or ability should have access to work, education, health care, and the other aspects of participating in society; and
2. Quality of life – clean air, green spaces, traffic reduction, reduction of CO_2, independence for children, protection of character of historic districts.

These values have led to the planning of multiple modes to provide efficient and convenient mobility for all which include;

- Cycling, for the relatively fit riding short distances, including large tricycles for senior citizens, and free bicycles;
- Buses making frequent stops;
- Metros, fast and independent of street conditions;
- Trains for longer distances; and
- Smart card, automatic payment and transferable between different modes.

In Copenhagen bicycles and public transportation are prioritized over cars in planning. Effort is put into continually improving the efficiency of public transport. Bicycles and public transport also receive greater funding. Copenhagen is eliminating car parking spaces at a rate of 2-3% per year which includes minimal parking even out of the city centre. For example *DR Byen* (DR Town) is the headquarters of the Danish national broadcasting corporation (DR) and employs approximately 2,700 employees but only provides 500 parking spaces.

As a result, 47% of Copenhageners do not own a car, 58% use a bicycle everyday, 26% use a car everyday and 25% use a bus every day. The commuting modal split in Copenhagen is outlined in Figure 8 below.

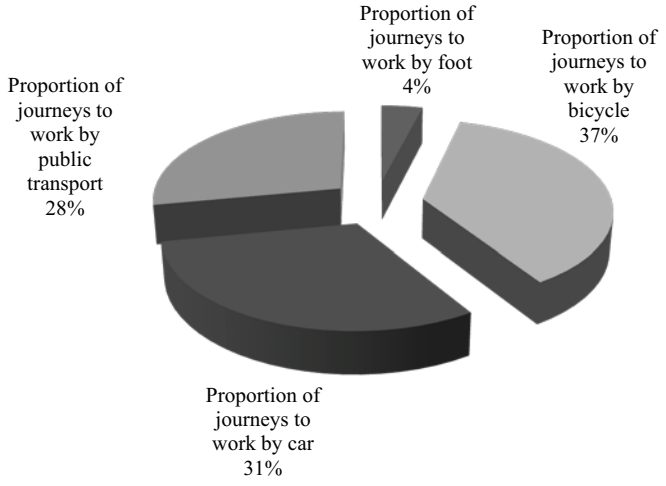

Figure 8. Copenhagen Modal Split

3.2 Transport Policy

The Greater Copenhagen Region is a metropolitan area of 1.8 million inhabitants on almost 3,000 square kilometers in the North eastern corner of Zealand. Besides the two cities - Copenhagen and Frederiksberg - the region has three counties - Copenhagen, Roskilde, and Frederiksborg - and 46 other municipalities. The five major counties have

owned a transport company, known as HT or Copenhagen Transport, for more than 25 years. The Greater Copenhagen Authority - Hovedstadens Udviklingsråd (HUR) was launched in July 2000, and is directed by a council of 11 regional politicians. As the key government authority, the HUR-council has responsibility for solving political difficulties within their competence, and for the HUR budget. The counties raise money for HUR's operating budget through the county income tax, which also funds some investment, with the balance coming from national government.

Copenhagen is seen as leading best practice in the implementation of transport policy. This is for a number of reasons outlined as follows:

- Integration of land use and transport;
- A strong emphasis on the integration of the public transport network, especially at interchanges (with timed connections between buses and trains, for example);
- High quality bus transport. This has been achieved through the introduction of competitive tendering, with considerable emphasis placed in the contracts on quality, with a number of incentives on operators to reward them for high quality service;
- Other transport policies, such as pedestrianisation, traffic calming, parking policy and cycling policy, especially in the urban centres within the Copenhagen agglomeration, that have been seen to support policy objectives aimed at reducing car use; and
- High levels of funding, but also imaginative ways of delivering that funding – for example with the Ørestad metro line.

This good practice has been achieved by voluntary co-operation between the five main municipalities in the region, together with concerted action by the regional public transport body (HT, now HUR). The existence of a regional public transport body has been of significant benefit to the region's public transport system, compared to the fragmented system that existed prior to the creation of HT in 1974. In addition, the dependence on the private sector for the provision of bus services in the Copenhagen region has provided major opportunities for improvements to services.

3.3 Cycling

Copenhagen has been called the most liveable city in the World, and it has a realistic vision to become the World's best cycling city

Copenhagen city council carries out a "Bicycle Account" bi-annually. This account is an assessment of cycling development in Copenhagen, dealing with city cycling conditions, new initiatives as well as the way in which the Copenhageners themselves perceive cycling facilities. The first bicycle account was published in 1992. The most recent account is based on 2008 statistics and includes telephone interviews with 1,025 randomly selected Copenhagen residents. The bicycle account also includes data form Denmark's Department of Transports "Transport Survey of Transport Behaviour" – research carried out by the department involving the continuous collection of information on the transport behaviour

Therefore it is known that cyclists in Copenhagen travel a total of 1.2 million kilometres by bike every day, the equivalent of cycling to the moon and back twice! Copenhagen however is not a natural bicycling city, like many of Ireland's towns and cities presently. In the early 1960's it was a city renowned for cars, traffic jams, and pollution. In 1962 the city created its first pedestrian street, the Stroget (the longest pedestrianised street in the world), and every year since then Copenhagen has allocated more and more of its public space to bicycles, pedestrians and people who just want to sit and take a load off. 34% of Copenhageners commute by bicycle.

Copenhagen's city government, along with Jan Gehl's public space research institute, is constantly measuring and analyzing street usage. After finding that the majority of the city's bike accidents were taking place at busy intersections they began striping them in blue. They are now studying whether these blue paths are doing anything to reduce casualties.

Copenhageners follow and respect the rules of the road. The vast majority of Copenhageners will get off their bicycles and walk when they come to a pedestrianised street like the Stroget. People stop at traffic signals. They stay in their lanes. Cyclists follow the rules of the road because they are a legitimate mode of transportation and they have

their own infrastructure. It is possible to bike across the entire city in 45 minutes.

Bicycle planning has the same status as public transport planning in Copenhagen. In 2002 one third of the city's road construction budget went towards cycling improvement. Fees and taxes for vehicular purchase, use, and parking have increased and continue to increase. As a result in Copenhagen there are over one million bicycles, which equates to one for every resident.
The Copenhagen bicycle network consists of over 180 miles and was built over the course of almost a century. Bicycle traffic is considered a distinct traffic category with its own separate road area, on par with motor and pedestrian traffic.

Copenhagen's larger streets feature travel lanes for cars, then sometimes a semi-separated bus lane, a stone kerb, then a slightly elevated cycle lane, then a pedestrian area. At most intersections cycle lanes are clearly marked in blue paint and separated from pedestrian walkways. At intersections bicycles have the right of way.

Copenhagen has set up 125 parking areas and stocked them with 1,300 specially designed bicycles with spoke-less wheels and puncture-proof tyres. A 20-kroner coin releases the key and one is free to ride anywhere with the bicycle.

3.4 Public Transport

Public Transport in Copenhagen comprises buses (including boat buses), trains and a metro. Copenhagen operates one public transport system which includes same fares, tickets and the ability to transfer freely between different modes. Transport planning emphasises public transport making buses and trains more convenient than trains. Certain streets have limited or no access to cars.

The Copenhagen Metro is a rapid transit system serving Copenhagen, Frederiksberg and Tårnby in Denmark. The 20.5 km system opened between 2002 and 2007, and has two lines, M1 and M2. Approximately 118,000 passengers use the Metro daily. Trains leave every 3 to 6 minutes. High priority is given to providing easy access to other means of public transport at all stations. The new metro was not funded by taxes; instead a new district was established south of Copenhagen called Ørestad. This land was owned by the government and the government constructed the new metro to bring people to Ørestad district. With the Metro the land then became more valuable and allowing the government to sell the land to private developers and using the funds to pay off the loans for the Metro and other infrastructural expenses.

3.5 Summary of the Key Transportation Concepts in Copenhagen

Today 37% of Copenhagen's commuters cycle to work or education. By 2015 the city aims to raise this to 50%. The city is committed to further improving bicycle infrastructure and developing campaigns and to promote urban development in ways that consistently incorporate and give high priority to cycling. Copenhagen's most recent bicycle account portrays that cyclists and non-cyclists prime motivation for more cycling would be more and wider cycle tracks and fewer cars. The city also aims to reduce motor traffic by introducing road pricing. The legal procedures for introducing road pricing, however, are not as yet in place.

Copenhagen operates following the idea of thinking mobility rather than traffic control, prioritizing bicycles and public transportation over cars. The city strives for a flexible multi-modal mass transit system. It is clear that efficient, reliable, safe public transportation can entice people to reduce car use. Copenhagen has made undesirable travel behaviours inconvenient and expensive.

4 ODENSE

4.1 Introduction

Odense is the third largest city in Denmark and the main city of the island of Funen. As of the 1st of January 2009 the population of Odense Municipality was 187,929. More than 150 different nationalities live in Odense among them are several international students. All in all 16,320 students attend higher education in Odense. 21,928 children live in Odense and they have more than 250 playgrounds to play in.



Figure 9. Odense – National Cycle City of Denmark

The city lies close to Odense Fjord on the Odense River. Its railway station lies on the route between Copenhagen and Jutland, the peninsular mainland. A 7.5 m deep canal, dug from 1796 to 1806 gives access to the town from the fjord. Accessibility to Odense was greatly increased when the ferry service between the two main Danish islands, Zealand and Funen, was replaced by the Great Belt Bridge which opened to rail traffic in 1997 and to road traffic in 1998. When the bridge opened, it was the second longest suspension bridge in the world. Its construction greatly cut transportation time between Odense and the Danish capital, Copenhagen.

4.2 Odense Four Year Programme

Odense City supported by The Road Directorate and Odense Municipality, and the Danish Ministry of Transport, conducted a travel behaviour change programme between 1999 and 2002. This "Smarter Travel" type programme aimed solely cycling and at further increasing the city's modal share of cycling and the number of bike trips and improving the safety of cyclists.

The Danish Ministry of Transport had already named Odense as Denmark's National Cycle City, because it had been promoting cycling extensively for many years prior to this programme. Since the 1980s, Odense has created an extensive cycling network comprising more than 350 km of cycle paths and lanes. In the 1990s attention focused on the improvement of traffic safety and comfort and to bicycle use promotion. Consequently, Odense experienced a growth in bicycle trips of approximately 50%, with a simultaneous drop in accidents of approximately 20% in the 1990s. Odense's modal split for journeys to work made by the city's population is outlined in Figure 10.

This four year programme comprising more than 60 demonstration projects had a budget of 3.5 million euro's. The programmes action plan concerned not only with building more cycle infrastructure, but also safety, leisure cycling, legal issues, accessibility, service, maintenance and quality.

It was envisaged that these measures would lead to improvements throughout Denmark and further afield, with Odense acting as a cycling laboratory and a model city. Odense's cycling promotion plan gives cyclists more rights: cyclists are allowed to cycle both ways along one-way streets, and they are given more space, for example through the construction of new cycle paths.

There have also been numerous awareness-raising campaigns, with particular emphasis on new types of campaign. It was apparent to the municipal authorities that brochures were not enough to change daily travel behaviour. Instead the municipal authorities confronted the people of Odense directly with the issue of cycling, establishing close contact with the general public and in particular with employers and employees.

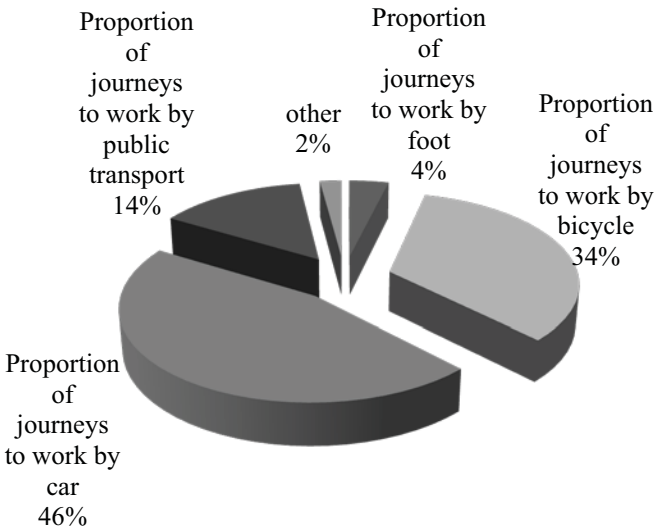

Figure 10. Odense Modal Split

"Action Planning" became the key words for Odense's strategy - a strategy to engage participants physically in order to "reach" them mentally. The strategy worked continuously towards establishing

a close contact with citizens in general, and especially to employers and employees. Focus was placed on action, social experiences and person-to-person contact between campaign staff and participants.

As previously mentioned, the project consisted of 60 different sub-projects which were conducted between 1999 and 2002. The objective was to encourage people to ride their bicycles instead of driving their cars, to improve safety for cyclists, and to give bicycles priority over cars. The main target group were commuters. These projects involved a combination of means, such as top priority to bicycles in town planning, regulation of motor traffic, technical initiatives, and campaigns. Emphasis was also place on quality in the construction and maintenance of cycling areas, and how they motivate people to use their bicycles. Campaigns played a crucial part of the strategy of Odense Cycle City. Experiences in Odense clearly showed that it was crucial to continuously accompany investments in physical improvements for cycle traffic with campaigns in order to promote, motivate and secure cycling. Many of the campaigns were directed towards children and young people (students) - the philosophy was that "it is easier to establish good than to change bad traffic habits".



Figure 11. Bicycle Pump Station in Odense

4.3 Campaigns

Campaigns included the following:

1. **Cycle to Work Campaign**
   - Aimed at companies via direct mail to 2,00 workplaces;
   - Advertisements for the campaign;
   - Postcards;
   - Handing out 3,000 ice-creams as part of the campaign;
   - Pins for all participants;
   - Pin patrol awarding prizes for pin holders; and
   - In 2002 – 10,000 participants.

2. **Test a Cycle Trailer Campaign**
   - Trailers were offered free of charge for one week;
   - 10 trailers and 6,000 parents got the offer;
   - 45% of the users normally travelled by car.

3. **Cycle Duckie Campaign**
   - Cycle Duckie (Odense is the birthplace of the author of the Ugly Duckling – Hans Christian Anderson) became the mascot for one of Odense Cycle City's campaigns;
   - Used to motivate new young cyclists; and
   - More than 3,000 children and their parents competed in cycling the most to and from day care centres for 2 weeks.

4. **Permanent Cycle Lights**
   - Attached via magnets to the wheel, no batteries, fixed at the cycle;
   - 16,000 signed up, 2,000 got free lights;
   - 98% happy cyclists; and
   - -32% accidents as a result.

5. **Get Rid of the Sack**
   - Aimed at middle aged men;
   - Advertisements, bus ends, people dressed up as a "sack of potatoes" promoting the campaign;
   - Go-cards to 84,000 households; and
   - 75% remember the campaign.

6. **Cycle Route Planners and Cycle Counters and Scanners**
   - Allowing citizens to plan their cycle routes online;
   - Cycle computer model allows cyclists to draw their preferred route;
   - Counters – cycle traffic information comes from the cyclists;
   - Barometers counting cycle traffic have been exported to other European cities; and
   - Cycle detectors – include cycle lotteries and monthly rewards.

7. **Cycle Simulator**
   - Cycle training for 12 year old children;
   - Linked to the national practical cyclist exam; and
   - Based on attitude not rules.

The following outlines a number of the sub-projects considered as good examples of action planning for more cyclists in Odense.

4.4 Highest Quality for Cyclists

At Odense Central Station, a new state of the art underground parking lot for bicycles was opened, featuring video surveillance, music, special locking arrangements, water fountain, lockers, and showcases for bicycle equipment.

Finest quality also extends to the maintenance of all bicycle paths in Odense. Resurfacing, keeping the paths free from dirt, garbage, broken glass etc., and snow clearing are carried out at the same high level as on the largest roads in Odense. In addition, road inspectors are required to regularly inspect all bike paths.

4.5 Cycle Trailers for Children

This campaign involved in total 7,500 parents. 10 trailers were sponsored by their manufacturers, and each trailer went to a kindergarten for 2-3 months at a time. One employee was responsible for instructing the parents. It was thought that cycle trailers offer good training for the parents and show a good role model for the children to become cyclists too. An extra advantage is that one can carry two children plus some luggage at ease. All parents with children in kindergartens were also offered to borrow a trailer for free for one week. Parents were also given the option of buying a trailer afterwards.

4.6 Campaigns for School Children

During the period of 1955-1971, Denmark had the highest rate of child mortality due to road accidents in Western Europe. However, only one out of six accidents occurs on trips to and from school. Cycling is the most common mode of children's transport and the use of bicycles increases with age. In response to this a project in Odense started more than 20 years ago and includes all 45 schools of the city. For each school, maps of the area have been drawn, showing where the children actually move around and the places, which they consider dangerous. (The study also includes routes to and from organized activities).

Based on the study, proposals to improve the traffic environment for children were worked out. All results and proposals for each school were included in a report. Since 1981, a total of around 200 projects have been implemented. The most common measures have been slow-speed areas, traffic islands and separate foot and bicycle paths. New techniques has been developed, e.g. to get the acceptance of speed humps on roads with city buses. Speed registration on twelve 30-km/h roads showed a decrease in speeds from 45 to 31 km/h. The effect on the total number of accidents has been a reduction of 82 %. Furthermore the accidents are now less serious. A new national pilot project permits automatic speed control in Odense. Control is used on school roads with heavy traffic, where road humps cannot be accepted. Looking at the traffic accidents involving children there has been a drop of 24% from 1994 to 1999, even though that there has been some fluctuation in the meanwhile.

Adding data from the hospital to double the number of accidents doesn't affect this conclusion. New statistics show that the percentage of children cycling to school in Odense today varies between 24 and 73 % at different schools.

4.7 Green Wave for Cyclists

When cycling in Odense it is actually possible to arrive at a green light every time at a specific traffic light in Odense. To guide the cyclists, Odense has developed a 'running light', the first of its kind, which makes a green wave. If you don't cycle in the green wave you have to speed up or slow down to avoid the red light. The idea behind "the green wave" is to give the cyclist some priority in traffic and to make travelling more comfortable. Project manager Troels Andersen from the city of Odense thinks stated that "The light signals are usually put up for the sake of cars. Therefore many cyclists have to stop a lot of times. If a cyclist adjusts the speed to the green wave, the ride will be more comfortable." according to Troels Andersen "Physically cyclists take up much less space than cars on the street. And that means that the high technological solutions that car drivers have often not are seen in the cyclists context. It has been important to us to demonstrate that new technology also can be used in connection with cycling."

4.8 Evaluation

The many campaigns carried out in Odense were led to make people sensitive and interested in the daily use of bicycle. As a result of this transport

policy and bike promotion during a 10 year period (1990-2000), cycling increased by more than 50%, Odense's four-year promotion programme (1999-2002) was assessed in detail following its completion (Evaluering af Odense – Danmarks Nationale Cykelby, 2004). During an extensive survey conducted among citizens, almost half of them appeared to be informed about the initiatives that had been taken during the four years. The measures best remembered were infrastructural improvements: short-circuits, green wave, safe bicycle parking facilities. The people of Odense were quite satisfied with the physical facilities: 82% finds that Odense has excellent bicycle facilities. Campaigns were remembered far less easily. The assessment also proved that development in traffic safety had been positive during the four years. To illustrate the development in bicycle use, the assessment compared the period 1999-2002 with 1994-1997. The share taken up by bicycles in all trips by citizens of Odense aged between 16 and 74 rose from 22.5 to 24.6%. There was a simultaneous, notable decline in public transport (8.2 to 6.6%). The increase in bicycle use remained within the fluctuations appearing in the time sequence from 1993 onwards. The bicycle share largely fluctuated around 25%. This was the case in 1993, later (1996) it fell until slightly over 20% and it has since been fluctuating between 23% and 27% - with 2000 as top year.

To summarise:

- In three years the number of cyclists in Odense increased by 20%;
- The number of accidents declined by 20% during the same period;
- 25% of Odense's citizens choose the bicycle as their mode of transport for getting to work or their place of study and for other errands;
- 80% of Odense's children walk or ride a bicycle to school; and
- There are 18,600 inhabitants in Odense 500 kilometres of cycling routes.

5 GRONINGEN

5.1 Introduction

Groningen is a medium sized city located in the northeast of the Netherlands, approximately 200 km from Amsterdam. Groningen is the capital city of the province of Groningen. The city was founded in the middle Ages and the street pattern of the inner city continues to show characteristics of that period.



Figure 12. Groningen City

The city comprises a compact spatial structure. The city has a population of approximately 180,000 inhabitants (2009). Groningen as well as being an important economic centre, is a university city catering for over 30,000 students and the average age of the city is low at 33 years.

Five radial routes characterize the main road network structure of Groningen today. These primary routes connect the city centre with its suburbs. A ring road which these radial arterial roads branch out from in turn connects the suburbs to the surrounding region. Around the car-restricted, partly car-free city centre a car park distribution ring operates comprising eleven parking garages for the inner city and the adjoining residential quarters. The city also has an extensive cycle network, good public transport, and a large pedestrianised zone in the city centre. Public transport (bus and train), is also characterised by this radial structure, running largely parallel to the main car traffic structure, especially along the routes leading from the ring roads to the inner city. All city and district public transport merges in two connected public transport nodes in the city centre and central station area.

In the past 25 years Groningen has had a consistent transport policy which has aimed at encouraging the use of the bicycle and discouraging the use of the car for short distances in particular. The

historic structure of the city of Groningen offers limited possibilities in terms of extending car infrastructure, which consequently encourages the transfer of mode share to bicycle use. Groningen is known as the bicycle city of the Netherlands with a bicycle use share of approximately 40% for all trips. The contributing factors to Groningen's cycling success are policy, engagement, and continuity. Successions of policies have emerged with the same concept that cycling is an integral part of urban renewal, planning and transport strategy. Through the provision of proper infrastructure and amenities cycling has increased over time and today the main 46 routes of Groningen's cycling network are used daily by approximately 216,000 citizens. Cycle traffic has received priority over motorised traffic and through the promoting of cycling as the main mode of transportation, city planners, local authorities, and cycling advocates have played an important part in establishing the city's reputation as a city which provides sustainable urban living.

1977 brought the introduction of a traffic circulation plan for Groningen's which introduced cycling policy to the city. In 1976 a plan was devised for Groningen which would extremely affect car traffic. The main idea of the plan was to ban through traffic from the inner city with the exclusion of bicycles and buses. Due to the experimental nature of the plan, the Dutch government considered it to be of more than local significance. Consequently the government provided financial and other support for the implementation of the plan.

Following the introduction of this circulation plan, the inner city moved its focus more towards the bicycle and essentially away from the car. A lot of time, money, and energy were invested in cycling infrastructure and the inner city was transformed into the pleasant living area it is today. The city is now famous for having one of the highest percentages of bicycle usage in the world. In 2002, Groningen was awarded as 'Bicycle City' by the Dutch cyclist organisation called Fietsersbond. Figure 13 conveys Groningen's modal split for journeys to work.

5.2 History of Transport and Traffic Policy

Groningen's success as a 'bicycle city' results from the changes in the city's urban design and policies over time. Since the late 1960s the municipality of Groningen has been the leading European city in terms its traffic plans and spatial planning policies; maintaining a vision of a 'compact city' and implementing policies which have lead to a car free city centre, with all areas easily reachable by bicycle. However, the provision of such a city has not always been easily achievable.

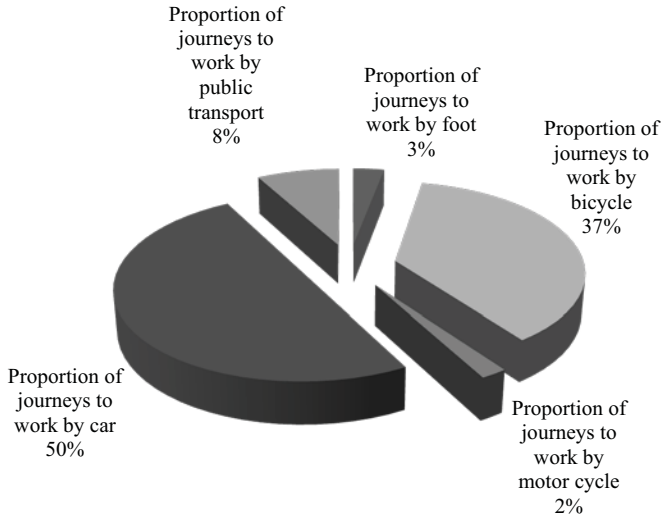

Figure 13. Groningen Modal Split

During the 1950s and 1960s most cities and towns in the Netherlands were providing for vehicles, some even removing bicycle paths in order to make space for the car. Between 1955 and 1968 car traffic in Groningen became threefold; and between 1960 and 1968 it doubled. Car ownership in Groningen in 1965 was slightly above the national average (110 cars per 1,000 inhabitants compared to the national average of 100 cars per 1,000 inhabitants). In Groningen, car traffic was growing rapidly, as was suburban sprawl. At this time there were no restrictions for cars driving through the city and very few cycle routes to the city centre existed.

This "motor car is king" situation was also happening in Ireland during this period. During the 1960s the conflict between the growing space demands of car traffic and the limited amount of space available within the city centre led to plans for a ring road around the inner city, one through residential districts and another entirely outside the city. The available space within the city was adapted, where possible to accommodate car traffic. In 1969 the municipal executive presented a traffic circulation plan: "Verkeerscirculatieplan Groningen 1968-1969". This outlined plans for a distribution

ring road which would closely encircle the city centre. According to the plan, the traffic structure would be composed of three tangents: the inner, middle and outer tangent. However, the plan showed much resistance and the municipal executive finally came to the conclusion that, apart from economic development, a livable, small-scale inner city as a venue for all kinds of activity and with a mixture of living, working and shopping functions favoring pedestrians, cyclists and public transport was an alternative worth considering.

During the 1970s there was a change in policy. This meant the end of the construction plans of the inner, middle and outer tangents. Only the distribution ring road was fully transformed into an arterial road consisting of four to six lanes in the 1970s. The dissatisfaction of Groningen's population and its municipal government with the then existing situation led to a "Memorandum of Objectives" in 1970. This gave the chance of improved conditions and reduced the plans for ring roads to a proposal for a single ring road through the newer residential districts. This "Memorandum of Objectives" comprised the following aims:

- Pedestrians would have space to move without being constrained;
- There would be a fairer sharing of public space between different forms of movement;
- Public spaces would be used for a greater variety of purposes;
- Public spaces would be made pleasant places in which to pass time;
- Excessive noise level would be avoided; and
- Air pollution would be kept at a low level.

Local authorities at this time changed the emphasis of urban planning and development in Groningen. The centre of the city was to be considered as the 'living room' for its people. The basic concept used in urban planning was based on the 'compact city' vision, which placed an integrated transport system high on the agenda – for an inner city favoring the combined use for pedestrians, cyclists, buses and other means of public transport.

A new version of the traffic circulation plan was made in 1975. This plan based on the Memorandum of Objectives, and was agreed in principle by the municipal council in 1976. Work started in the summer of 1977 and the new traffic system was introduced on the 19th of September 1977. The revised traffic circulation plan divided the inner city into four sections and one ring road (the distribution ring road mentioned previously) was built encircling the city and reducing access to the city centre by car. The result was an inner city which is entirely closed off to cars; it is only possible to travel between sectors by walking, bicycle or public transport.



Figure 14. Groningen City Centre Today

What has encouraged the use of bicycles over all other sustainable modes of transport is the vast expansion of the cycle network. There are many traffic free bike lanes which run from the outskirts of the city to the city centre, which makes cycling the most viable mode of transport for most journeys. The traffic circulation plan was not intended to remove all car traffic from the city centre, but to bar through traffic from the city centre and to guide car drivers heading for the city centre to nearby car parks as directly as possible.

In the 1980s Groningen's transport policy was aimed at accommodating ever growing rates of motor traffic through more investment in infrastructure, which in fact led to more and more traffic. Where one congestion spot was eliminated the traffic problem simply shifted further down to another street. In the 1980s and 1990s the application of traffic circulation made it possible to bar through traffic from city quarters and to concentrate it on a limited number of ring roads. The completion of the full ring road system in 1987 made closure possible of what is known as the Lelieboulevard, which ran through the Noorderplantsoen - Noorderplantsoen is an urban public park in the city of Groningen. After about

ten years of discussion on the pros and cons a pilot closure followed in 1993, succeeded by a referendum in October 1994 resulting in a very narrow 51% majority and the decision to close the road was made. Assessment shows that bicycle traffic in the Lelieboulevard and Noorderplantsoen has increased by approximately 30%. More than half of all car traffic that used to take this road through the Noorderplantsoen chose the ring road system after the road closure.

In 1989, the municipal council recognised that attempts to accommodate more traffic were futile and leading to a poor quality environment and outward migration of the population from the city. All attempts to accommodate more motor vehicles were abandoned in 1990. At the same time a 'master plan' was established for the whole of the entire region. This put in place policies to provide greater mobility by public transport and bicycles and to restrict the growth in motor traffic. Priority was also given to promoting journeys on foot, by bicycle and via public transport. Motor traffic was restrained apart from goods and service vehicles in the city centre of Groningen. 'Quality of Life' was also an important part of the policy and emphasis was placed on road safety and the introduction of 30 km/h zones in all residential areas. Between 1989 and 2000, 23 million Euros have been invested in cycling infrastructure and making cycling faster and more convenient in the city, and the annual amount continues to grow. Investments have been made on expanding the network of cycling lanes, improving the pavements, incorporating bridges for cyclists, more bike parking facilities.

During the 1980s and 1990s a parking policy became an increasingly guiding policy instrument and was strictly implemented in the city. Car parking with associated time restrictions was introduced in a broad radius around the inner city. Park and Ride areas were created combined with city buses and other high quality public transport. At present there are eleven parking garages (Park and Ride), offering a total number of 3,600 places Public transport is strongly promoted too, including a Park and Ride Citybus system.. In 2004 over 1.3 million people made use of the Citybus.

5.3 Groningen Today

Office buildings, services and mixed use developments have all been developed in the vicinity of public transport interchanges and are also highly accessible by bicycle. There has been an extensive programme of urban renewal with high quality accommodation located within the city. As mentioned previously strict parking policy has been implemented and the distribution of shopping facilities has been designed so that people can do their daily shopping in neighbourhoods with the city centre acting as the main centre for shopping. In addition, supermarkets are not permitted adjacent to motorways or within industrial sites. It is reported that initially these measures were regarded as severe and there was hostility to the plans, particularly by retailers, who thought their premises would become inaccessible with a subsequent drop in turnover. However, 20 years on and visitors to the city have increased. More people have moved back to the city, increases in retail trade and a high quality environment entirely dominated by pedestrians and cyclists and not motor traffic has been created. The spatial policy of Groningen continues to focus strongly on a compacts city. Within a 3 km radius from the heart of the city 78% of all inhabitants and 90% of all jobs can be located.

To summarise Groningen City offers the following today:

- A reclaimed Grote Markt which was once a traffic roundabout and today is the city square-a centerpiece with markets and street cafe's;
- A city divided into four sectors within the ring road which cannot be crossed by motor traffic (i.e. it is impossible to get directly from one sector to the other by car and requires use of the ring road);
- 11 Park and Ride sites provided on the outskirts of the city for visitors to the city centre;
- Shuttle services for employees living on the outskirts of the city and in rural areas;
- Cycle lockers located at rural bus interchanges to allow those in suburban areas to bike and ride;
- An extensive cycle network with direct radial routes into the city centre from the suburbs to the city centre with journey times of 20 minutes;

- Maximum accessibility by bicycle such as permission for cyclists to travel in the opposite direction of one way streets and permission to turn right on a red traffic signal when the road is clear and it is safe to do so;
- Integration of bike and rail at the central rail station through the provision of guarded bike shelters for up to 5,000 bicycles; and
- Newly built neighbourhoods are no more than 6 km from the city centre and along major bicycle and scooter 'roadways'.



Figure 15. Bicycle Parking in Groningen

6 DELFT

6.1 Introduction

Delft is a town of approximately 96,000 inhabitants, located in Southern Holland in the centre of the Dutch Randstad between the capital The Hague and the City of Rotterdam. Delft has an historical centre and a dense residential area. Delft was one of the first towns in the Netherlands with a consistent and persistent cycling policy that is still continuing today. Since the early 1980s Delft designed and realized a cycle network in the city. A slogan: "Delft fietst - Delft cycles" was put in place to encourage cycling across all ages. Delft is connected to Rotterdam via a cycle free way.

6.2 Cycling Policy 1979 to 1985

A bicycle plan was implemented in Delft from 1979 to 1985. Key efforts were made in the construction of equipment which could help to complete the town's network of cycle tracks. This plan included several measures from the construction of infrastructures to traffic regulation. The main characteristic of the Delft bicycle network plan is its hierarchy.



Figure 16. Delft Town

It is made up of three networks at different spatial levels - the city level, the district level, and the sub-district level, each having its own functional and design characteristics:

- "Town" level: the cycle network is a grid of cycle tracks which are about 500 m apart. This network is intended to carry large numbers of cyclists to the main centres of activity: schools, universities, bus stops and railway stations, offices and industrial areas, sports fields and leisure areas. The physical barriers which are the canals and railway lines require heavy infrastructures to be built if detours are to be avoided;
- "District" level: the cycle network has two main functions, which are to serve the various strategic points of the district (schools, shops, etc.) and provide a link to the "town" network (to join it and to return). At this level, tracks are 200 to 300 m apart. The flow of circulation is less dense than for the "town" network; the distances covered are shorter. The developments required at this level are less heavy: cycle lanes, little bridges, etc.
- "Sub-district" level: the cycle network links residential areas with local amenities. The routes covered by this network are usually short and often covered by children. The cycling infrastructures are about 100 m apart and are mixed: they are also used by pedestrians.

Delft town council allocated €12,705,846 to finance its cycling policy between 1982 and 1992. 80% of this amount was from subsidies granted by the Dutch Minister of Transport, Public Works and Water Management.

6.3 Cycling Policy 1999

A new bicycle plan was made in 1999. Priority was given to cycling areas that experience bottle-necks, and a study was done to identify these areas. Second, further facilities, and accommodations were made for bicycle parking and storage to make cycling a more comfortable option. Funding was received to accomplish these measures.

Local operators including The Delft Entrepreneurs Federation, the first Dutch Cycling Federation (ENFB), the University and the "Priority to Children" organization, had a large influence on the plan's contents. The following outlines the objectives of the plan:

- to encourage the use of the bicycle as an alternative means of transport to the car for distances up to 7.5 km by creating new cycle tracks, linked to the existing network and limiting problems engendered by other forms of traffic;
- to increase the modal share of bicycles even further;
- to reduce the number of accidents to cyclists by improving infrastructures;
- to reduce the number of accidents involving schoolchildren through traffic education;
- to increase the parking facilities for bicycles in the neighbourhood of the original sites and destinations by providing cycle garages, particularly in residential areas, and by converting car parks into cycle parks; and
- to reduce the number of cycle thefts by creating more guarded cycle garages and installing deposit services for bicycles (particularly close to the two railway stations, schools and businesses) and by equipping cycle parks with efficient anti-theft devices.

6.4 Evaluation

So far, the Delft bicycle network consists of:

- building of two tunnels;
- construction of three bicycle bridges;
- reconstruction of seven intersections;
- creation of space to wait in front of cars at 14 traffic lights;
- 3.3 km of new connecting bicycle tracks;
- 2.6 km of streets that are bi-directional for cycles, but one-way for cars;
- 8.5 km of bicycle lanes and tracks parallel to roads; and
- Repaving of 10 km bicycle path with asphalt.

Through the policy implemented, the average number of daily trips made by bicycle has increased by 12%, rising from 25 000 to 28 000, and the total distance covered by 6 to 8% depending on the type of trip. The increase in the number of trips is mainly attributed to men, using their bicycle more often to go to work or study. The average distance of a trip has risen from 3.7 to 3.9 km, which seems to reflect an increasing interest in cycling among the inhabitants of the town's peripheral districts. Note that this increase has not occurred to the detriment of the time needed to make the trips, which has remained the same, and therefore tends to demonstrate the effectiveness of the network. An evaluation study has shown that these results are mainly due to a change in use of the network. The following factors have contributed towards this improvement:

- the hierarchical structure is an important part of town planning because it gives priority to urban centres and links between the various levels described;
- 60% of the kms covered by bicycle were at "town" level, which only represents 30% of the total length of the network; and
- The use of cycle tracks has increased, rising from 30 to 35%, while at the same time, the use of roads for cycling has fallen from 45 to 40%.

Improved comfort and safety therefore seem to encourage residents to choose the bicycle as a means of transport. The number of cars travelling into the town centre has fallen, which is good for its attraction and creates a pleasant atmosphere. Modal distribution has risen from 40 to 43% for the bicycle. Cars and walking have remained stable at 26% while public transport has fallen from 6% to 4%, although the number of passengers carried has not changed.

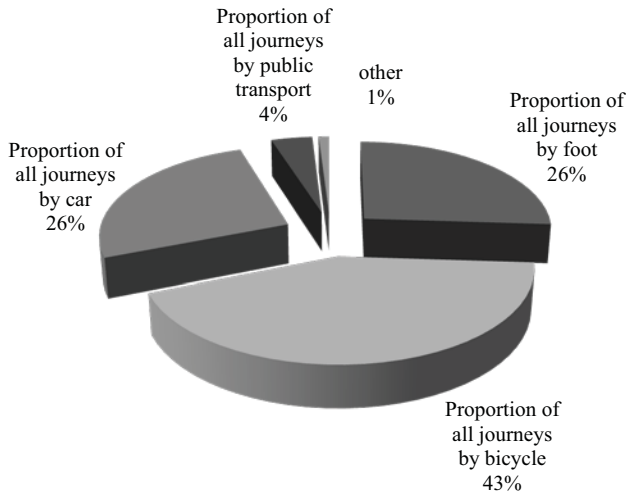

Figure 16. Delft Modal Split

7 FREIBURG

7.1 Introduction

Since the 1970s Freiburg has been developing this reputation as Germany's ecological capital. By 1986 the City had a vision for a sustainable city reliant on an ecologically-oriented energy supply, today its solar, energy efficiency and transport programs are among the best in the world. Over 10 years CO_2 emissions have been reduced by more than 10% per capita, there has been a 100% increase in public transport use – with up to 35% of residents choosing to live without a car Freiburg is living proof that solar can work in the Northern Hemisphere. Freiburg is a sustainable city driving down CO_2 emissions by regulation, incentives, design, long-term commitment, and policy reform.

In 1996, the City passed a resolution, the Climate Protection Concept, to reduce CO_2 emissions to 25% below the 1992 level by 2010. Target areas include energy (i.e. in buildings, private households and businesses, and in industry), and transport. Emissions from waste, farming, and forestry are not included because they are negligible. The majority of the City's emissions reductions have come from co-generation. Almost 50% of the City's electricity is supplied through a CHP steam and gas plant called Rhodia. Heat from the plant is used for industrial purposes for the chemical industry.

In this Belfast sized University City, commuter car journeys have fallen from 60% in 1970 to 43% in 2009, taking 4,000 cars per day away from the city centre. The main points of this traffic policy in Freiburg have always been: expanding the public transport network, completing the cycling network, realising 30 km/h zones in staying areas, limiting the number of lanes on some main roads or narrowing them down, and applying a controlling car parking policy. Figure 18 shows the city's commuter modal split.



Figure 17. Freiburg City

7.2 Transport

The focus of inner-city traffic policy was placed on public transport due to the preservation of the historic city centre. A highly innovative urban transport policy lies at the core of Freiburg's transformation. The medieval city centre has been progressively pedestrianised, revitalising its use. In 1972 the decision for the maintenance of the light rail system was made. As a consequence, the city centre was pedestrianised in 1973 and in 1983 the first new tram route was opened. In 1990, a 30 kph zone was introduced for almost all residential streets, except main roads. The old streets have been widened to take the trams.

65% of residents live within walking distance to a tram stop. Public transport informs the planning system, for example in 1997 when a new suburban district was under construction, Rieselfeld, a new tramline was included in the first construction phase. In the new district of Vauban, if residents sign a contract stating that they will live without a car, the requirement to buy a parking space in the district garage is waived, reducing the cost of their housing.

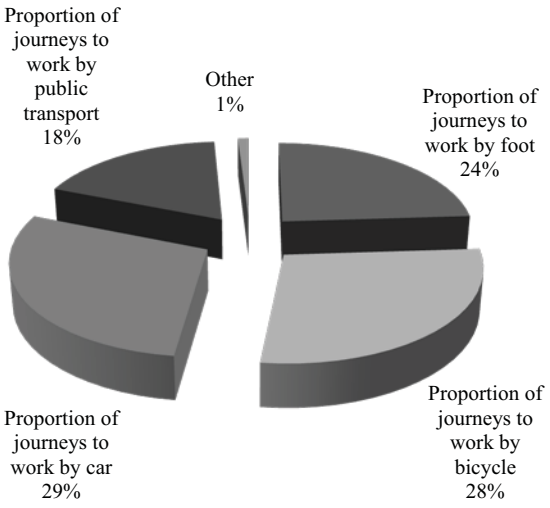

Figure 18. Freiburg Modal Split

The tram system (Stadtbaln) is integrated with regional train routes and bus services. The public transport system is reliable, frequent, and convenient. In addition with a monthly pass for 45 Euros which covers the whole region and multiple modes, the system is also affordable. Almost a third of daily commuters use public transport.

7.3 Cycling

A cycling plan was drawn up in 1970, and the city now has over 500 km of bicycle paths, and a third of all journeys are by bicycle. There are more than 5,000 bicycle parking spaces in the city, with more at tram stops for "bike and ride" commuters. The main railway station has parking and other cyclist facilities for 1,000 bicycles.

Since 1976 Freiburg has been conducting an active cycling policy at an annual investment of €836,000. In the past ten years a considerable effort has been put in towards further expansion of the cycling network. This has resulted in a coherent, fine-mesh cycling network, connecting all quarters with the city centre and with each other.

This cycling network now has a total length of 500 km, of which 160 km are cycle paths (114 km along main roads, 46 km autonomous), 130 km through 30 km/h areas (of which 90 km are cycle lanes) and 210 km on country roads. It is now possible to traverse the city by bicycle without any interruption in an east-west direction, using the car-free bicycle route known as Dreisam, a wide road lining the bank.

Another detailed study was performed in 2002. It concerned mapping the time each mode of transport took to travel from certain city locations to the Bertoldsbrunnen, a tram-and-bus node in the heart of the city. This map shows that bicycles are the quickest mode of transport for distances until ca. 3 km: from the first layer encircling the city centre it is a fifteen-minute bicycle ride to the Bertoldsbrunnen. This node is within thirty minutes' reach by bicycle from practically all over the core of the city, just as quick as public transport. Thanks to the presence of a few quick main roads this takes a car only twenty minutes in many cases. Public transport is quicker than the bicycle only when you start from a few immediate station surroundings in the remotest western quarters. It is not likely that there will be many cities that would even realise the value of such knowledge about competitive positions of different modes of transport.

The active cycling policy of Freiburg most certainly contributed to the fact that bicycle use has almost doubled in size since the early '80s as regards local trips. In 1999 Freiburg inhabitants took their bicycles for 28% of their local trips. This is ca. 22% of all trips. At the same time, car use for local trips dropped heavily: from 38% to 29%. All of them together, the environment-friendly modes of transport (public transport, bicycle, walking) cover 70% of all local trips.

7.4 Integral Policy

The success of this cycling policy lies mainly in the coherence of overall traffic policy. Cycling policy is an integral component of a traffic policy consistently promoted by the Freiburg's environment association (Umweltverbund) while car use is being discouraged at the same time. Add to this the city's spatial policy, aiming to keep distances short to avoid unnecessary traffic. This has also resulted in new, partly car-free residential quarters like Rieselfeld and Vauban, both situated within cycling distance from the city centre, and an active location policy for large companies and supermarkets. To summarise Freiburg's car free initiatives':

- The old town centre became car-free in 1973, and in 1990, a 30 km/h zone was introduced for almost all residential streets, except main roads;

- Freiburg introduced a low-cost flat-rate monthly "Environment ticket" for the region-wide bus service in 1991, and there has been a 100% increase in people using public transport since 1980;
- In the new district of Vauban, if residents sign a contract stating that they will live without a car, the requirement to buy a parking space in the district garage is waived, reducing the cost of their housing;
- Around 30 - 35% of the residents have chosen to live without a car. In 2004 and 2005 the city will open two major new tram lines, one from the city centre to Vauban. As a result of these initiatives, motor vehicle use fell from 38% to 32% between 1982 and 1999, in complete contrast to the trend in almost all other central European cities.
- A cycling plan was drawn up in 1970, and the city now has over 500 km of bicycle paths, and a third of all journeys are by bicycle. There are more than 5000 bicycle parking spaces in the city, with more at tram stops for "bike and ride" commuters. The main railway station has parking and other cyclist facilities for 1,000 bicycles.

8 DISCUSSION AND CONCLUSION

The six “Smarter Travel” cities described in this paper highlight how best practice has been achieved through strong and continuous co-operation between local government and public transport authorities which together prioritise bicycles and public transportation over cars.

Cycling policy forms an integral element of each city’s overall transport policy, encouraging the use of the bicycle and discouraging the use of the car. Each city has been and continues to be committed to improving bicycle infrastructure and developing bicycle promotion campaigns which encourage their citizens to become sensitive and interested in the daily use of the bicycle. Community engagement has developed “Smarter Travel” cultures where sustainable transport is regarded as the norm.

In addition this best practice has been achieved through integration of transport policy with each city’s spatial policy, altering the emphasis of urban planning and development and aiming to keep distances short to avoid unnecessary traffic. This type of urban planning is based on the ides of a compact city, which relies on an integrated transport system to provide a city favouring pedestrians, cyclists, buses and other public transport users.

Although the six chosen cities offer unique journeys in terms of achieving high sustainable urban transport use, there are notable parallels which could serve as best practice examples for Irish towns and cities. It is obvious from this precedent study that the main contributing factors which appear to be decisive in achieving ‘Smarter Travel’ behaviour change comprise community engagement, community involvement, soft measures (information) which support hard measures (infrastructure), support of government local leaders and the removal of incentives for car travel (i.e. penalizing unsustainable travel and rewarding greener alternatives).

This study encompasses a wide range of physical interventions and measures to reduce car use which have been implemented through engagement with citizens. All this has been accompanied by behaviour change over time across these European cities which have had a sustained impact. Travel behaviour change programs have an important role to play, however, they alone will not deliver the Department of Transports vision for a sustainable travel and transport system for Ireland, we cannot afford to lose sight of the importance of the whole system and each of its components; the importance of improving the underlying infrastructure combined with the encouragement of travel behaviour change.

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THE RELATIONSHIP BETWEEN TRANSPORT CARBON DIOXIDE EMISSIONS, URBAN FORM & SOCIO-ECONOMIC CHARACTERISTICS FOR THE GREATER DUBLIN AREA.

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ABSTRACT

The design of cities, strategically and locally, is important in terms of the travel behaviour it enables. The polarities of the options are in car dependent, low density urban sprawl, or public transport orientated urban development, with higher density development provided at public transport nodes. Much of current urban life lies somewhere in between - as hybrid development forms - there are few examples of 'pure' walking or cycling, public transport or car cities or towns. The future emphasis will be in exploiting the potential for increased usage of public transport, cycling and walking and low carbon vehicles. This requires an increased localisation of activity and mobility patterns, whilst still maintaining internationalised accessibility. Urban spatial structure - including population size, density, job-housing balance, mixed land use, the location of development, accessibility and local neighbourhood design – can also be used to help design of the sustainable city. Urban form should be targeted at improving the quality of life in our cities and towns and in enabling a sustainable transport future. This paper intends to explore further the relationship between urban form and transport carbon dioxide emissions at a disaggregate level. Using the Census of Population of Ireland 2006 Place of Work - Census of Anonymised Records (POWCAR) Dataset it is intended to examine urban form and socio-economic factors in terms of their influence on transport carbon dioxide emissions. To examine the hypothesis, the transport carbon dioxide emissions vulnerability index developed by Carty and Ahern, (2010a) for the Greater Dublin Area will be compared against various urban form and socio-economic characteristics, thus allowing the most sustainable urban forms in the Greater Dublin Area to be identified.

Keywords: Transport carbon dioxide emissions, urban form, and sustainability.

1 INTRODUCTION

It has long been recognised by transport planners that a change in land-use will often have transport implications. To date the hugely complex set of interdependencies in the transport and urban planning field is not well understood - and has been under-researched - yet plays a critical role in the design of the sustainable city. This paper intends to address issues relating to the design of cities, including the links between urban form and travel. Here it is argued that the structure of cities (strategically and locally) is influential in determining the resulting transport related energy and emissions. A critical point is that the design of the sustainable city needs to be influenced by the global environmental agenda: transport investment, for example, needs to be working towards the goal of reduced carbon dioxide transport emissions. To reduce levels of car dependence and trip lengths, planning decisions must have an instrumental role through establishing and implementing clear development principles based on sustainability.

Since all travel is generated by land use and the type and intensity of the activities that take place on parcels of land, the potential significance of land use planning as a means of managing the total demand and type of demand for travel is self-evidently large. However, there are few case studies of land use schemes which have quantified the real travel-reduction effect. The main reason for this is the difficulty of comparing before and after conditions for an instrument that takes so long to implement and for effects to be felt. Despite the comparative lack of research on the effect of land use policies and thus on their significance, some observations may be made concerning the effects of land use patterns on travel behaviour.

Per capita private car travel tends to decline:

• With increasing population and employment density;

• With increased land use mix, such as when commercial and public services are located within or adjacent to residential areas;

• In areas with attractive and safe streets that accommodate pedestrian and bicycle travel;
• With the presence of a strong, public transport system, particularly when integrated with supportive land use.

Land use planning measures can contribute, but these may take a long time to take effect. The conversion of existing building stock and neighbourhoods takes place at a slow rate of change – a typical figure for the rate of turnover of the urban fabric is 1% per year. Therefore, the switch from, say, a policy of minimum housing density and maximum parking standards to a policy of maximum housing density and minimum parking standards will take some years to have an effect, since a large proportion of the existing urban development will already be laid out to previous standards.

On the other hand, this long term nature means that land use planning measures can set the physical pattern upon which mobility patterns are based for generations. Put another way, once good practice has been invested in, it is less easily undone. The suburbs of the early 20th century – built to low density but before mass car ownership – have meant that car-orientation has been 'built in' to those localities for decades. This also implies that if we can 'build in' sustainability-oriented (e.g. travel-minimising) features to new development, we could expect these to be a worthwhile investment prevailing over decades to come.

This paper attempts to clarify the debate concerning the effects of land use intensification on transport energy and emissions including socio-economic factors. To do this the paper examines the effect of various land use and socio economic attributes on transport carbon dioxide emissions in the case study area; The Greater Dublin Area (see Figure 1) and discusses the results of the analysis in terms of land use policy. The results of this research can then be used to assess the transport related carbon dioxide emissions of future development plans and therefore allow greater transport sustainability to be achieved through improved design of the location and form of major new development.

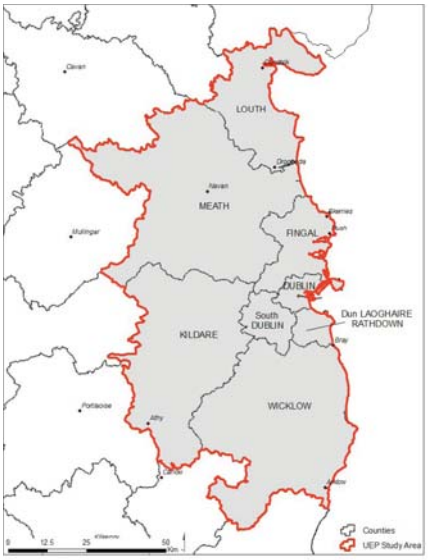

Figure 1 Study Area: The Greater Dublin Area.

2 TRANSPORT AND URBAN FORM

The relationship between urban form and transport as a topic of research has increasingly become more prominent as efforts to attain more sustainable lifestyles and sustainable travel behaviour are sought. Urban form provides the framework for the location of housing, employment and other developments such as health, education and leisure facilities. The role of urban form, at the strategic and local levels, would appear intuitively to be critically important in facilitating the transportation network. Therefore we would expect different urban forms to be easily associated with different travel behaviours. For example in the case of high density, public transport oriented development one type of travel pattern and for low density sprawl, we would expect to see considerably different travel patterns. However, much of the previous empirical research remains inconclusive.

Some have argued that certain land use variables, for example density, are strongly associated with energy consumption in travel (Newman and Kenworthy, 2006; Holtzclaw and Haas, 2002). Among planners and policy makers, the results of these and similar studies have commonly been interpreted as a foundation for recommendations of

a more concentrated urban development pattern, characterised by densification rather than low density development at the outskirts of the city, and public transport improvement rather than urban road construction. However, not all research shows this to be the case. Researchers further acknowledge the existence of an intricate relationship between urban form and socio-economic and attitudinal factors affecting travel behaviour (Cervero and Duncan, 2002; Krizek and Waddell, 2002). Others add a further dimension in contending that the suburbanisation of the labour force has actually led to reduced trip lengths, with both residences and jobs being located in the suburbs (Gordon and Richardson, 1989), (Carty and Ahern, 2010b) In fact, it is not unusual for studies to conclude that the effect of density, and indeed the effect of other land use features, derivates largely from socio-economic and mostly attitudinal and lifestyle variables. In their view, a great deal of self-selection operates in high-density transit-orientated environments, whereby individuals choose to reside in such areas precisely because their values predispose them to a public transit and walking lifestyle (Cervero, 2002). Frey (1999) concludes that no unambiguous data exist to indicate whether a compact or a more spread out urban structure contributes to a higher or lower energy consumption. There are also other issues raised around the acceptability of various policy stances, particularly the public acceptability of compaction (Breheny, 1992); it is contended here that suburbanisation has been stimulated by lifestyle choice and that attempts towards urban compaction are futile. The complexity inherent in the rationale for travel appears to make analysis of urban form and travel problematic.

3 THE RESEARCH FRAMEWORK

This paper seeks the urban form and transportation conditions that contribute to the contrasting levels of transport related carbon dioxide emissions in the Greater Dublin Area. A variety of variables have been used in the international literature to represent 'travel behaviour'. These include distance travelled, commute time, mode of travel and time of departure (for examples see Levinson and Kumar, 1997; Stead, 2001 and Cervero, 1996). Considering the wealth of disaggregate data available for this study and increasingly important topics of global warming, sustainability and energy security, it was felt that a combination of the variables available, in the form of the transport carbon dioxide emissions vulnerability index developed by Carty and Ahern, (2010a) for the Greater Dublin Area (see figure 2), would best represent 'travel behaviour' overall. The data necessary to calculate the index were obtained from the Census 2006 Place of Work - Census of Anonymised Records (POWCAR) Dataset. The POWCAR dataset which was derived from the 2006 census includes only persons who at the time of the census ere enumerated in a private household, were 15 years old or over, were enumerated at home and indicated that their present principal status was working for payment or profit, see Carty and Ahern (2010a) for emission factor calculations.

When analysing the travel behaviour the literature has mainly been concerned with the impact of land use characteristics, and until relatively recently, has ignored the potential impact of socio-economic effects. However as noted by Stead (2001) the impact of higher densities on travel behaviour may be the result of a variation in income or socio-economic group, rather than land use per se. this is not to discount the impact of land use factors on travel behaviour, however. But it serves to illustrate that there may be other factors as well as the highly published land use factors, namely socio-economic characteristics, which also influence travel behaviour. Here, we analyse the influence of both land use and socio-economic characteristics in order to view the impact of each on travel behaviour. In addition, tests for multicollinearity are conducted in order to investigate the extent to which land use and socio-economic variables are correlated with one another.

Independent variables cover a range of urban structure characteristics as outlined below;

Resident population density at the origin and destination, employment density also at the origin and destination, distance from urban centres, urban versus rural trips, jobs-housing balance and rail catchments.

These variables were selected on the basis of the relationships between socio-economic characteristics and transport energy consumption identified in the literature (Banister et al., 1997). In terms of the selected independent variables, these variables were selected on the basis of data availability. Regarding the socio-economic variables, income was not available data wise so the following variables were used instead; gender, age, household size, socio-economic group, industrial group and the number of cars available for use.

A multiple regression analysis was carried out using these variables in order to establish key socioeconomic and land-use variables that explain the variation in transport CO_2 emissions.

The study is heavily empirical in its approach as it tries to test the relationships between land use variables, and their effects individually and in combination on carbon dioxide emissions in transport.

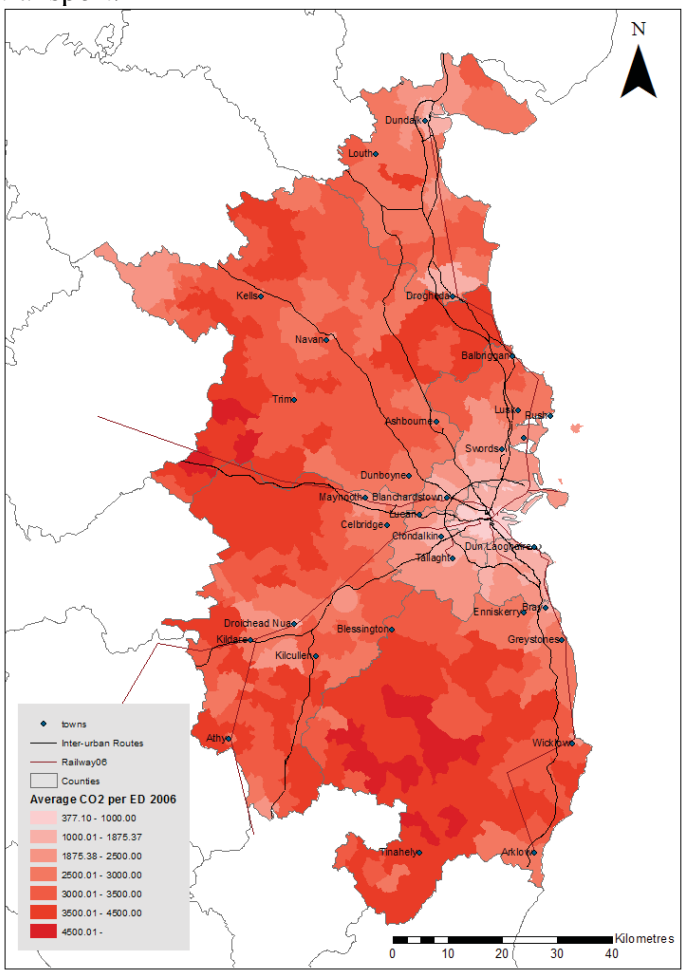

Figure 2. Average transport CO_2 emissions per ED for the GDA in 2006.

4 REGRESSION ANALYSIS VARIABLES AND RESULTS

Table 1. Model results

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.568	0.323	0.323	1814.55399

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	2,743.284	23.982	114.390	0.000
Male	249.319	6.009	41.493	0.000
Age1519	-701.546	23.940	-29.304	0.000
Age2024	-454.714	11.887	-38.253	0.000
Age2529	-197.985	9.893	-20.012	0.000
Age3034	-14.950	9.643	-1.550	0.121
Age4044	-18.266	10.321	-1.770	0.077
Age4549	-79.888	10.860	-7.356	0.000
Age5054	-182.037	11.718	-15.534	0.000
Age5559	-243.716	13.081	-18.631	0.000
Age6064	-283.015	16.133	-17.543	0.000
Age6569	-368.908	31.089	-11.866	0.000
Age7074	-516.824	58.392	-8.851	0.000
Age75	-414.971	76.128	-5.451	0.000
segB	-50.287	10.106	-4.976	0.000
segC	-113.095	9.419	-12.007	0.000
segD	-358.032	8.012	-44.689	0.000
segE	-274.532	11.635	-23.595	0.000
segF	-524.538	11.368	-46.140	0.000
segG	-651.291	18.228	-35.731	0.000
segH	-370.350	22.344	-16.575	0.000
segI	-1,061.784	68.517	-15.497	0.000
segJ	-1,085.853	58.202	-18.657	0.000
segZ	-611.574	50.289	-12.161	0.000
Indgrp1	-786.188	44.717	-17.582	0.000
Indgrp2	-370.387	14.699	-25.198	0.000
Indgrp4	-638.237	13.746	-46.430	0.000
Indgrp5	-491.588	16.334	-30.096	0.000
Indgrp6	-465.271	16.392	-28.384	0.000
Indgrp7	-605.051	14.993	-40.354	0.000
Indgrp8	-721.644	15.725	-45.893	0.000
Resident_Persons	-87.524	2.357	-37.139	0.000
Resident_Workers	-173.848	4.955	-35.083	0.000
Cars_or_vans	498.857	3.609	138.217	0.000
Jobs_Housing_Balance	0.471	0.397	1.186	0.236
Distcity_org	67.267	0.280	240.269	0.000
Distcity_dest	-72.599	0.278	-260.997	0.000
Urban_org	6.104	12.334	0.495	0.621
Urban_dest	432.989	14.121	30.663	0.000
Rail_Access	-313.047	5.969	-52.449	0.000
LNresDense_o	-69.047	3.945	-17.501	0.000
LNresDense_d	-48.651	3.511	-13.857	0.000
LNemDense_o	-85.280	2.934	-29.071	0.000
LNemDense_d	-83.753	2.309	-36.278	0.000

4.1 Variables

Many of these dummy variables are self explanatory. The first of these is equal to one if male and zero otherwise. Age is categorised by a number of dummy variables of five-year age groups. SEG refers to the socio-economic group of persons aged 15 years or over who are at work and is determined by their occupation and employment status, seg 'A' = 'Employers and managers', 'B' = 'Higher professional','C' = 'Lower professional', 'D' = 'Non-manual', 'E' = 'Manual skilled', 'F' = 'Semi-skilled', 'G' = 'Unskilled', 'H' = 'Own account workers', 'I' = 'Farmers' 'J' = 'Agricultural workers' and 'Z' = All others. Indgrp refers to eight broad groups of industry types; '1' = 'Agriculture, forestry and fishing', '2' = 'Manufacturing industries, mining, quarrying and turf production, electricity, gas and water supply', '3' = 'Construction', '4' = 'Commerce', '5' = 'Transport, storage and communications', '6' = 'Public administration and defence', '7' = 'Education, health and social work' and'8' = 'Other'. No. of residents and resident workers refer the number of each in a household. No. or cars/vans refers to the number of cars or vans available for use in the household. Regarding the land use variables; population and employment densities and Jobs housing balance (ratio of jobs to number of households per ED) refer to the ED level. Distance from the CBD and Rail Access use the centroid of the ED.

4.2 Results

Regression analysis was used to identify the key socio-economic and urban form characteristics that explain the variation in transport CO_2 emissions per person. The results of the regression analysis suggest that there are a number of urban form and socio-economic characteristics that are correlated with transport energy and emissions. The research analysis is summarised in a series of key findings. This aims to further our understanding of the complexity of travel behaviour and the subtlety of the relationships with urban structure.

On average males emit more transport CO_2 emissions than females, with a coefficient of (249.319), this is quite low but is significant at the 1% level. This ties in with research by Naess (1996). Regarding age, 35-39 year olds were held constant here, with age variables resulting in an inverted u shaped curve, where the opposite ends of the scale of the 5 year age groups (15-19 and 70-74) emit the least and 30-34 year olds emit the most transport CO_2 emissions but they are found to be insignificant.

As the number of residents in a household increases, the transport CO_2 emissions per person decreases. This would be in agreement with the findings of Banister et al. (1997), who report that household size is negatively correlated with transport energy consumption. This finding would suggest trip sharing and also may be due to the lack of availability of private transport to each individual in a household, leaving them with the least energy intensive alternatives of public transport and walking/cycling.

Transport CO_2 emissions also decreases as the number of resident workers in a household increases. Once again this may point to more trip sharing and may also be due to the lack of availability of private transport for each individual.

Regarding socio-economic group (SEG), transport CO_2 emissions is highest for SEG 1 (employers and managers) and decreases as we progress down through the scale, with the exception of 'Own account workers' and 'All others' which both deviate slightly from the rate of decline. This relates to findings by other researchers that income is positively correlated with transport CO_2 emissions (Wee, 2002). The car availability variable indicates the number of cars/vans available in each household, as the number of cars available increases so to does the transport CO_2 emissions.

In terms of industrial group, Indgrp3 which is 'Construction' was held constant, all of the other industrial groupings are found to have significantly lower transport CO_2 emissions than 'Construction'. Considering the general amalgamation of different industries in each group these finding should be treated with some caution.

In relation to the land use variables, we will begin with density, which we examined at both the origin and destination and included residential density (persons per hectare in each ED) and employment density (number of jobs per hectare in each ED), but due to the highly skewed nature of the GDA, where high residential and employment densities are only found with in the central core of Dublin City we will analyse the natural log of the density variable. An inverse relationship is found between residential population density and transport CO_2 emissions at both the origin and destination. Lower residential densities are associated with higher transport energy consumption patterns and higher densities with lower energy consumption. This result is in agreement with results from Newman

and Kenworthy whose findings support the argument for higher density development leading to lower energy consumption. These relationships appear to be quite weak in comparison to some of the socio-economic factors.

Likewise employment density at both the origin and destination is found to have reduced transport CO_2 emissions at higher densities.

As expected, increased distance of an individual's residence from Dublin's City centre is associated with higher transport CO_2 emissions in the commute to work, while the opposite holds for increased distance of the destination from Dublin City centre, as the distance of the destination increases from the city centre, the transport CO_2 emissions decline. This may suggest that further dispersal of employment away from the city will lead to decreases in transport CO_2 emissions.

The jobs-housing balance (number of jobs per ED/ number of households per ED) is found to be insignificant.

In terms of transport CO_2 emissions and whether the individual is travelling to or from an urban ED (Urban ED is defined as having greater than 1.5 people/hectare), people travelling from an urban ED were found to be insignificant whereas people travelling to an Urban ED emit far more transport CO_2 than people travelling to rural EDs.

Finally, regarding rail access, residents located in an ED within 1km of a railway station (LUAS, DART or Train) for both their origin and destination emit less transport CO_2, than those without this accessibility.

Using linear regression and combining the land use and socio-economic variables from the POWCAR data reveal that 33% of the variation in transport CO_2 emissions can be explained by both the land use and socio-economic variables. More of the variation in transport CO_2 emissions per person was explained by the land-use than socio-economic characteristics, with socio-economic variables accounting for 13% of the variation in transport CO_2 emissions and urban form variables accounting for 20% of the variation. The variance inflation factor (VIF) was examined in the regression analyses to check for multicollinearity. According to Hair et al (1995), a usual threshold for identifying high collinearity or multicollinearity between independent variables is a VIF value in excess of 10. Of the large number of regression analyses carried out in this study, there was no case in which the VIF values exceeded the value of 10, so multicollinearity can be ruled out for this model.

5 DISCUSSION

The negative impacts of transport systems on air quality, noise, and energy consumption are the basic motivation for studies aimed at innovative and effective remedies. This paper seeks to examine how land use factors and socio-economic factors can play a role in transport CO_2 emissions.

Analysis of the POWCAR dataset identifies that there are limited variations in transport CO_2 emissions in the commute to work with regard to individual's socio-economic characteristics and that urban form factors play a greater role in determining individuals transport CO_2 emissions. The main variables to reveal this variation in terms of urban form factors are; urban destinations, distance from Dublin's City centre, residential densities and employment densities at both the origin and destination and proximity to railway stations. In particular, the analysis has also shown that urban form and transport CO_2 emissions are interlinked, and the analysis shows a definite but weak negative correlation between transport CO_2 emissions and residential population density. This finding encourages the recommendation, from a land-use planning perspective, of raising residential population densities especially in close proximity to railway stations.

The regression analysis suggests that urban form characteristics explain more of the variation in transport CO_2 emissions than socio-economic characteristics. Socio-economic characteristics explain just under 13% of the variation in transport CO_2 emissions per person whereas urban form characteristics often only explain 20% of the variation in transport CO_2 emissions per person. These findings would be in line with the likes of Headicar, (2009) who found Land use characteristics (settlement size, population density, public transport accessibility, jobs housing ratio) account for 11% of the variation in travel distance. Socio-economic characteristics account for 3% of the variation in travel distance (as previously mentioned travel distance and transport CO_2 emissions are highly correlated).

There is clear evidence of a link between the distance between home and the urban centre and transport CO_2 emissions per person. This finding is in agreement with the research of Hickman, (2007), who reports a link between the distance from an urban centre and transport energy emissions.

Clearly, the extent to which urban form might influence travel patterns may be lower than other

studies have previously indicated (where they have not taken socio-economic characteristics into account). However, this does not mean that land use does not have an important role to play in influencing travel patterns or cannot contribute to more sustainable travel patterns. The results of the study indicate that urban form characteristics such as density, proximity to rail and distance from urban centres have a role to play in promoting more sustainable development. Furthermore, the findings in this study would support the theory that higher-density land-use is inherently more energy-efficient although we have identified factors which diminish the foundations of the compact development policy and show that it is not the only alternative

The compact development policy would include the follow recommendations; combining developments in public transport (proximity to rail) and higher-densities, enables a more frequent and higher-occupancy public transport with lower emissions per passenger. Mixed-use developments, better housing location and building design, and support for local services can reduce travel distances to employment, education, health services, and shops and therefore reduce CO_2 emissions. These developments in turn encourage a shift in the mode of transport, and improve the safety and attractiveness of urban areas.

An alternative policy would include specific employment and services decentralisation matched with appropriate residential areas. Considering the vast stock of low density development in the GDA with its inherent car dependency and unsuitability for public transport support, placing employment and services in closer proximity to specific residential areas combined with the continued improvement in vehicle technology (see Commission of the European Communities, 2008a) would reduce trip distances and transport CO_2 emissions further within these zones. The evidence form the analysis suggests that increasing employment densities outside the metropolitan area results in reduced transport CO_2 emissions. Mixed land-use fundamentally aims to generate proximity between employment and residence, as a measure to promote reduction in transport CO_2 emissions, but if it is not planned and implemented in an orchestrated procedure with exact compatibility, it could result in the opposite outcome: raising CO_2 emissions.

Regarding the results from the socio-economic variables; in recent years the there has been an increase in the Greater Dublin Area of high density residential and commercial developments. This is a direct result of the widely held opinion amongst policy makers and planners in Dublin that high-density mixed use developments at major transport nodes is the preferred way to counter the rise of car dependency in the region (EPA, 2004; NESC, 2005). Along with this type of development, the largest growth in household type according to the 2006 Census was in single person households. This trend accompanied by the increased participation of females in the labour force, will according to the socio-economic results lead to increases in transport emissions. Policies should therefore be geared towards encouraging less car ownership and initiatives such as community based car pooling schemes and increased public transport provisions.

In light of the present economic crisis, employment has fallen significantly, with the construction, manufacturing and retail sectors bearing the brunt of the adjustment. Unemployment has risen to over 13 percent, having been below 5 percent at the beginning of 2008. In terms of transport, Ireland has witnessed the following trends in the past two years since the economic crisis began; House completions down to approximately 26,000 in 2009 from over 90,000 at the peak of the boom. Commuter numbers have also decreased with LUAS passenger numbers down by one million in 2008 and a further two million in 2009; Dublin Bus numbers down by 3 per cent in 2008 and an estimated 10 percent in 2009; Bus Eireann numbers down by 2 per cent in 2008 and 4 percent in 2009; New car registrations fell by over 34,000 in 2008, and dropped again by some 92,000 in 2009, although there have been increases again in 2010; Truck traffic fell by 12 percent in 2009 and the total number of private cars licensed has contracted slightly. This has resulted in a decrease in Energy use in transport for the first time in 2008 – by 1.3% to 5.6 Mtoe (42% of final energy use) due to the economic downturn. Transport energy-related CO2 emissions also fell for the first time in 2008, by 1.9% (SEI, Energy Report, 2009).

This latest economic situation heightens our awareness of the need to look at alternative approaches to sustainable transportation. In terms of the short to medium term there will be little if any development taking place which should encourage policy makers to look at alternative solutions to the transport sustainability problem, such as improving our existing transport infrastructure rather than focusing on compact development proposals. The current economic

climate will also help to reduce transport related emissions especially considering that we found that construction employees were among the heaviest emitters of transport carbon dioxide.

To conclude, our findings suggest that the compact city model is only one of many factors which can reduce energy and emissions and there are alternatives which have equally compelling evidence but in terms of policy are at the opposite end of the scale. The trend toward increasing mobility and dispersal is due to many complex factors and in the GDA there are factors such as, employment density at the origin, distance of the destination from the city and rural destinations which display reductions in CO_2 emissions for transport, which suggests that if we decentralise some jobs and services and relate them to residential areas we will also see a further decline in CO_2 emissions for transport.

6 CONCLUSIONS

In most developed countries, policy makers and urban planners consider that a denser, more compact city will lead to lower levels of energy consumption. As a result, many European countries promote the concept of the "compact city" on the basis of environmental arguments- namely as a way of reducing transport energy consumption and hence of contributing to the achievement of sustainable development. This paper has examined the relationship between transport CO2 emissions urban form and socio-economic characteristics with a view to investigating this remarkable political consensus. Some of our results support this view, particularly our residential and employment densities evidence but this has been shown to have a relatively weak effect on transport CO2 emissions within the GDA. Major changes in the form and function of cities, towns and villages are expected using the "compact city" policy. Inevitably such changes will have significant social and economic consequences. Given that many people and businesses have consciously chosen suburban decentralized environments which have lead to the existing sprawling urban form of the GDA. Many European governments, it seems, are expecting great things from the compact city approach. In the case of the GDA, the evidence suggests that emission reductions from urban compaction are likely to be disappointingly low, due to the relatively weak negative association between the factors. The evidence presented here suggests that a controlled decentralisation of employment and services to selected residential areas combined with improved vehicle technology and public transport could achieve the same if not better results in terms of transport CO2 emissions than the levels of emissions savings likely to result from even quite tough compact-city proposals.

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SOFTWARE

Data analyses, modelling and cartographic output was carried out using ESRI ArcGIS 9.2.

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TRANSPORTATION SCENARIOS: LOOKING FORWARD AND LOOKING BACK IN FOUR EUROPEAN CITIES

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ABSTRACT
The post World War II history of European urban transport in cities involves trajectories, switching points and socio-political choices. The paper contributes to our understanding of such choices by confronting the results of a scenario-building exercise carried out with urban experts in four European cities in year 2000 with subsequent developments. Already by 2000 urban experts were committed to sustainable mobility in terms of both spatial planning and transport technologies. They tended to link these aspirations to the broader European social model. However they did not expect such aspirations to be realised. Subsequent developments in the four cities show that while experts' expectations in relation to urban transport technologies were overly pessimistic, the cities have not moved significantly towards sustainable mobility and new forms of car-based mobility have emerged.

Keywords: Sustainable Mobility, Scenarios, Urban History

1 INTRODUCTION

Urban transport policy is interwoven with urban planning policy: choices of transport technologies and transport systems are to some extent choices of urban form. In other words, choices of technology are certainly not just technical choices and not even purely economic choices. Precisely because such choices involve values and politics in the broadest sense, they are open to social scientific analysis: we can ask *why* and *how* and *for whom* specific choices were made. Such social science also has to be historical: transport choices made in the past have very long term consequences, transport choices are themselves embedded in long lasting historical structures. Furthermore, transport choices inevitably look to the future: they involve assumptions about what will happen and, even implicitly, aspirations as to what *should* happen.

This paper addresses the last of these issues. It is about urban experts' expectations and aspirations for transportation in four European cities in 2000 and what happened to these expectations in the subsequent decade. Experts hoped that mobility in their cities would become more sustainable and less car-based. In fact the reverse occurred.

The paper begins by arguing that the development of urban transport involves *path-dependent trajectories*, in which institutional structures lock in a particular set of technologies, and *switching points,* which move development in a new direction. One such switching point appears to have occurred in *some* cities in Europe in the 1970s, and this can be linked to the emergence of a distinctive European social model. This raises the question tackled in this paper: to what extent policy makers across Europe became committed to transport technologies and urban planning which differed from that of the previous period.

The paper then outlines research carried in the year 2000 on urban experts' aspirations and expectations in four European cities. The main empirical sections of the paper use this research to assess whether these views do show the emergence of a new commitment to sustainable mobility; we examine experts' scenarios for the future of their city and their understanding of possible urban transport technologies. The paper then confronts these views with an initial sketch of subsequent developments in the four cities. It concludes with the suggestion that experts in 2000 failed to fully anticipate the development of a new form of 'post-modern' market-based automobilism.

2 PATH DEPENDENCY, SWITCHING POINTS AND SCENARIO-BUILDING

Car ownership and car usage have long become absolutely normal in all advanced societies. However, general discussions of 'automobilism' or

'automobility' can detract from the considerable diversity that exists both in the level of car ownership and in the level of car usage. Notoriously for example, car ownership and especially car usage are higher in the USA than in Europe. There are also well established differences between European cities in the extent to which people use for specific journeys cars as opposed to using public transport, or walking or cycling (e.g. Cameron et al, 2004). It is increasingly accepted that such differences have very little to do with the overall wealth of the city – rich cities often have low car usage and even low car ownership. Furthermore, within cities car ownership and car usage cannot be simply read off from income or occupation, since car usage also depends on location, life style and even personal ideology (Kaufmann, 2002). The fact that such variations exist increases the plausibility of public policies which attempt to reduce car usage.

Despite the growth of empirical sociological and even social historical research on urban transport in the last decade, our understanding of this diversity remains ad hoc and fragmented. Changes in the technological system of auto-mobility (the 'car system') needs to be located in broader accounts of social structure and social change. Political economy and historical institutionalism offer one possible framework. Thus we could differentiate between fordist (or modernist) and post-fordist (or post-modernist) forms of automobility. This could link car production and above all car usage to different social structures, different types of employment, different types of economic structure. We could contrast the regular and routinised journeys of the fordist period (home/suburb to work/city centre) with the more diffuse patterns of the contemporary city where most journeys are suburb to suburb and are more dispersed in time.

Such long term periodisations need also to be located in different physical geographical contexts. The great metropolises of 19th century Europe were built around a public transport system which was created before the advent of the motor car. By the 1920s cities such as London, Paris and Berlin had systems of trams, metros and suburban rail that allowed their inhabitants to move easily over a large densely inhabited area. In many ways the inter-war period was the golden age of public transport (Wolf, 1996). Unlike in the USA (with the partial exception of New York), these systems were not then destroyed. As any tourist will tell you, you do not need a car to explore a European city – you move around on foot and you extend your pedestrian journeys with relatively short distance journeys on public transport.

When World War II ended, most of Europe had not yet been shaped by the private car. Photographs of the bombed cities of Europe in the immediate aftermath of the war often show trams – presumably on rapidly restored tracks – threading their way through the ruins with hardly a car in sight. In the 1930s Germany had certainly embarked on its famous programme of Autobahn construction, but in fact Hitler's new motorways were largely empty. It was in Britain, or more precisely Southern England, that the private car first became an item of mass consumption. By 1939 private car ownership had reached two million and the car industry was producing 300,000 cars a year (Stevenson, 1984: 390f): the family car, just like the owner-occupied house in the suburbs, now became part of 'normal' life for the middle classes.

This normalisation of the car occurred in the rest of Europe only after World War II. During the 1950s the car became a key symbol of modernity, along with other mass produced consumer goods. Across Europe the car industry was at the centre of the mass production industry and car companies were national champions, often interwoven with the state or even in outright state ownership. The state was also crucial to the consumption of the car, planning and building new 'motorways', 'autoroutes' and 'Autobahnen'. However, even here Europe remained different to the USA. There the construction of the interstate highway system in the 1950s, claimed to have been the world's biggest construction project, along with the subsequent expansion of domestic airlines, ensured that US railways became marginal for passenger transport except in a few areas of the North East. By contrast, European railways were not destroyed, although many small rural branch lines were closed. There were major investment programmes in many systems after World War II, although they were not able to compete with road traffic especially in freight transport. Furthermore, road construction was uneven, with Britain only beginning a motorway construction programme in the very late 1950s.

Nonetheless, through the 1950s and 1960s the general direction of policy was clearly towards the motorisation of cities with American developments usually held out as indicating the future. Although car ownership remained well below US levels,

urban development usually involved the construction of urban motorways which began to destroy the fabric of the city.

During this period there was some limited expansion of underground railways in the very largest cities. In the 1950s underground metro lines were built in Rome and Stockholm. However, part of the attraction of the underground at this period was precisely that it could relieve congestion on the roads and so facilitate car traffic. In West Berlin by the end of the 1960s all the trams had been removed, to be replaced by buses and an expanded U-Bahn system – contrasting with the eastern part of the city where trams are still in use.

From the 1970s onwards however the development paths of *some* European cities began to diverge from those of America, just as at the same time European welfare states as a whole became more different to that of the USA. The radicalisation of the late 1960s and early 1970s generated new social movements which contributed to a radical change in urban policy. A new urban aesthetic re-valued the existing urban fabric, areas of the city centres began to be pedestrianised, plans for urban motorways were slowed and even abandoned. Within this, and very much part of the expansion of the welfare state of the decade, urban public transport was expanded in particular with investment in urban rail systems. Differences within Europe also grew. Whereas the 1970s and 1980s saw a dramatic investment in urban rail in German cities, there was virtually no investment within the UK. (Whitelegg, 1988:48f). The 1970s are therefore a switching point in European urban transport trajectories. *Some* cities in *some* countries begin to move down a different path.

In the 1990s there was a second wave of urban public transport expansion. Within cities there was an almost complete halt to new road projects, and it became widely accepted that urban transport problems could not be solved by road building. Public transport was promoted, but now with slightly different arguments than before. There was a new concern for the quality of urban life, often linked to notions of urban economic competitiveness. Public transport was one of the policy areas increasingly appropriated by sub-national governments at urban or regional level. Indeed, public transport became a crucial area of activity for the resurgence of city and regional government across Europe. Furthermore, effective urban public transport was increasingly seen as contributing to environmental sustainability by reducing car usage within urban areas. In the new century, would these changes become built into the trajectory of more European cities? Above all, would car usage finally decline in importance as new transport systems developed in tandem with more compact urban areas?

Achieving such changes would involve a paradigm shift in urban transport away from auto-dependence. The sustainable mobility paradigm (Banister, 2008) can be thought of as involving both technologies of transport and spatial planning. Central to sustainable mobility is reduced expenditure on roads and greatly increased provision of public transport. Sustainable mobility also involves measures that restrain car use through re-allocating road space and which directly encourage walking and cycling. Instead of treating transport as a derived demand ('predict and provide'), such planning tries to reduce the demand for travel, especially car-based travel. It means designing compact cities with accessible local facilities so that people can choose whether or not to own a car. In the most general terms, it marks a reinvigoration of the ideal of the European city (Kazepov, 2005), an ideal which at least in Britain had been abandoned by the end of the 19th century (Hunt, 2004).

Given that, as we have seen, political institutions and social structures have influenced transport technologies in European cities, such changes in technology in the future will also involve social and political change. However, the nature of these changes is far from clear and is often contested. For example, in the second half of the 20th century urban public transport in Europe was almost entirely provided by state owned companies. Today however many such enterprises have been privatised. While some claim that this will inevitably mean a decline in public provision, others argue that it will lead to better services and higher usage (Wickham and Latniak, 2010). Furthermore, although compared to the 1950s there certainly has been a greater acceptance across Europe of investment in public transport and of some restraint on car usage in cities, there is no universal consensus on individual policy measures, whether these involve road building, road pricing, improving suburban rail lines or building new metros.

Once transport technology is seen as even to some extent the result of socio-political choices, then clearly people's beliefs about transport are important. It matters what participants in urban

politics consider to be possible, what they want and what they expect, and what connections they make between different technologies and between technologies and their socio-political context. One influential group in policy debates is what we might call the *urban experts*: urban planners, transport planners, lobbyists and interested academics. These are *not* those who necessarily make the decisions that matter, not least because many of the important decisions occur almost out of sight of the public political process. Although this too is variable, it does seem to be the case that *usually* rail projects, whether light rail or metro, have a higher public profile than road-building decisions, even though arguably the impact of a major road scheme is far greater, and that this can only partly be explained by the fact that many road schemes are incremental increases in capacity[1]. Equally, planning decisions such as new housing areas or retail parks have major impacts on transport in the city, but they too often occur out of the limelight. Nonetheless, to the extent that there is public debate, urban experts make an important contribution. Accordingly, their views are important in their own right.

A shift towards sustainable mobility raises questions about the views of such experts. Firstly, is there a new consensus across Europe amongst such people on the basic principles of sustainable mobility as outlined above? In other words, what changes in urban planning and transport technology do such experts want? Are they agreed amongst themselves? Is sustainable mobility seen as universally desirable and is it defined in the same way across Europe? Secondly, do these experts link their conceptions of sustainable mobility to a broader socio-political context? For example, is environmental sustainability seen as interwoven with social inclusion and social cohesion? For such experts, is market provision inherently inimical to sustainability? Finally, how do such experts evaluate the impact of their own views? They may have expertise, but does this mean that they have influence? Sustainable mobility may be desirable, but do they consider it achievable? Once again, differences in Europe will be important here and will tell much about European cities' chances of achieving sustainable mobility.

3 RESEARCH APPROACH

In order to answer these questions this paper uses data from interviews carried out in 2000 with urban experts in four European cities; it also confronts this material with actual developments in the four cities. This section of the paper describes how the original interviews were carried out and how they are re-utilised for the specific purposes of the paper.

The interviews formed the end of a project on 'scenarios of sustainable mobility' in European cities which I co-ordinated[2]. Two cities – Bologna and Helsinki - were chosen as examples of relatively good urban practice: they had explicit policies to reduce car usage, they had well developed public transport and relatively successful urban planning. In both cities political movements in the late 1960s and early 1970s had been decisive in pushing transport away from continued development of the motor car, and such policies had subsequently become part of a broad-ranging consensus within the city and were supported by a broad urban coalition. Two other case study cities - Athens and Dublin - were the exact opposite. They were notorious both for their traffic jams and for their reliance on the private car; they were an international byword for failed urban planning; they had ineffective public transport. Crucially the urban social movements of the 1960s and 1970s had passed them by, and there was no urban coalition to carry forward policies that restrained the private car.

The research was carried out by four separate teams, one for each city; overall co-ordination and analysis was carried out by the Dublin team[3]. For this stage of the project we invited urban experts and policy makers in each of the four cities to an extended group discussion. This discussion was intended to produce a scenario for sustainable mobility in the city. The scenario was defined as involving both the overall context of mobility and the specific technologies of mobility. Despite our best attempts, in every city meeting politicians from the established political parties were conspicuous by their absence, whereas representatives of the local Green parties attended in Dublin and Helsinki. In Bologna a large proportion of the group was

[1] Of course, the extent to which road building projects are debated is itself a political process.

[2] Project SOE1-CT97-1071 of the Targeted Socio-Economic Research Programme (TSER) of the European Commission; reports at http://www.tcd.ie/ERC/pastprojectcars.php

[3] Team members were: D. Balourdos, A. Mouriki, K. Sakellaropoulos, E. Theodoropolos, K. Tsakiris (Athens); E. Battalgini, F. Farina (Bologna); M. Lohan, P.Poli, J. Wickham (Dublin); M. Javela, T. Rajanti (Helsinki).

drawn from social activists; in Dublin various types of academics were particularly over-represented. While our original intention was to interview decision-makers in general, the members of the final groups do in fact correspond to those 'urban experts' defined above.

To structure the different aspects of the experts' views we used a slightly adjusted version of an established transport scenario model (Nijkamp et. al, 1998). This so-called spider model is based on the assumption that transport systems involve a number of *inter-related* policy aspects – spatial, economic, institutional and social. Each aspect can be conceptualised as comprising two distinct dimensions and each dimension involves a continuum between two extreme positions. For example, the spatial aspect of the scenario includes the dimension of **urban form**. Here one extreme would be the highly concentrated and high density **compact city,** at the other extreme would be the more **dispersed** and low density suburbanised city. Figure 1 presents the basic model as adapted from Nijkamp et. al (1998).

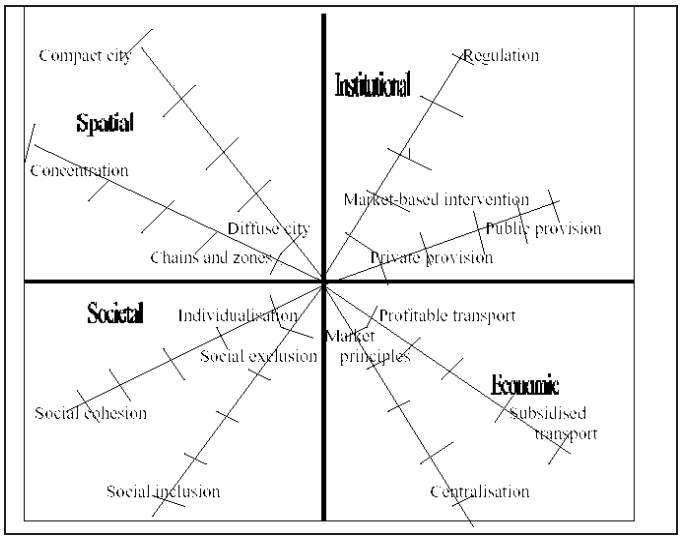

Figure 1 The Scenario Model

For this exercise we asked participants to choose points representing how they would *like* the city to be ('desired scenario') and how they *expect* the city to be ('expected scenario'). Furthermore, because the dimension takes the form of a numerical scale, it is possible to calculate the average value given to each dimension by all participants or indeed sub-groups of them[4].

The logic of the scenario is that the four different aspects and indeed their component dimensions are all independent. Thus a position on one dimension does not necessarily involve a similar position on any other dimensions. Furthermore, there is no explicit linkage between each dimension and the form of urban mobility. Equally, although the versions of the original spider diagram had been used to construct scenarios in which sustainability was an over-riding objective (Rienstra and Nijkamp, 1998), we made no explicit link between any dimension and environmental sustainability. How and why people make such links is one of the empirical issues we investigated.

While the spider diagram is concerned with the overall context of mobility, we also asked experts to evaluate various transport technologies. Once again they were asked to score these in terms of both whether they *expected* them to be widely used, and whether they *wanted* them to be widely used, in both cases using the same timeframe as for the scenario. The 'technologies' ranged from increasing the supply of roads, through improved public transport provision to regulation (e.g. road pricing) and alternative technologies (e.g. electric cars). Here again we treated the technologies as independent of each other. Of these technologies, increasing the road supply, whether by new roads or by road-widening, would be inimical to sustainable mobility, whereas all the other technologies could be part of a sustainable mobility package.

Whereas the spider diagram was originally to specify different possible scenarios for transport policy (e.g. Rienstra and Nijkamp, 1998), we treat here its elements in different ways. The dimensions or spokes of the diagram mostly refer to the possible *context* of sustainable mobility policy. We use the diagrams to specify the social, economic, institutional and spatial framework within which the experts saw mobility policy occurring. We do not assume any particular link between these dimensions and sustainability, but ascertain whether the experts themselves made such links.

One spoke of the spider is however treated differently. Given that sustainable mobility involves reducing the demand for travel through urban planning, we treat the spatial dimension

[4] It should be noted that where this diagram is used to present the scores each dimension has been reversed. Thus for example on the dimension 'urban form' the position 'diffuse city' is at the **outer** rim of the diagram, while the position 'compact city' is at the **inner** edge of the diagram. This was necessary in order to generate the charts with Excel while keeping the original scores.

'compact city/diffuse city' as a component of sustainable mobility itself[5].

Each team followed guidelines for the meeting which had been circulated by the Irish team. The meeting began with a presentation of the key findings of the research project. The team then explained the model and illustrated by showing the scenario for the city which they themselves expected; they also prepared their own desired scenario, but did not present it to the meeting.

We then asked the participants to fill out a questionnaire *in* the meeting. The questions referred directly to the policy dimensions of the model with some additional questions in relation to specific technologies. After this data collection stage, the results were immediately analysed using the SPSS statistics package to generate mean scores of the participants' policy choices and preferred policy outcomes. These results were then mapped onto the model and presented to the group towards the end of session.

While the questionnaire data was being analysed, the meeting was used to form a focus group discussion. Here the experts were asked to explain the choices that they had made on the different dimensions of their desired and expected scenarios, the extent these took into account environmental and social concerns, whether they felt that their desired scenario was possible within a 'business as usual' course of development, what factors they believed shaped their expected scenario and what would be needed to move in the direction of their desired scenario.

Each national team wrote up a report of their meeting following an agreed template. These reports were then edited and collated together with an introduction and analytical conclusion to form the workpackage report for this part of the research project.

[5] The status of the other spatial dimension, 'European spatial organisation', is more ambiguous. It could be argued that if urban development occurs in a series 'chains and zones' this is perfectly compatible with the cities themselves being relatively compact, and would reduce travel demand more so than if development is concentred in a few mega regions. The coherence of the spider model would therefore be enhanced if the scoring of this dimension was reversed.

4 EXPERTS' SCENARIOS

Figure 2 represents the average expected and desired views of all four expert groups. On all dimensions except that of European spatial organisation, the experts' desired positions are closer to the centre of the web than their expected positions. If as suggested above, the scoring of this dimension was reversed, the picture would be completely consistent.

4.1 Experts' desired scenarios

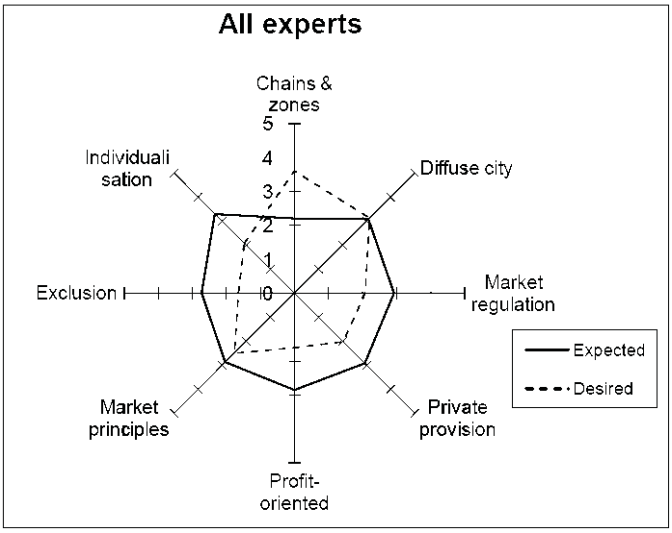

Figure 2. All experts' expected and desired scenarios

We begin our analysis by investigating the differences between the cities in terms of the experts' aspirations. Figure 3 presents the desired scenarios for the four groups of experts. The spatial aspect generated most disagreement. In terms of regional development (*concentration* versus *chains & zones*) most experts wanted what they considered a balanced population development rather than the concentration of growth at a few major centres. However, within the Finnish group there was no consensus. One set of participants welcomed the trend towards concentration of population in a few major urban areas, largely on the grounds that this was the only way they could receive adequate services. In most countries such a deliberate policy of rural depopulation is rarely explicit, though in the past it has been part of social democratic regional planning in Sweden. By contrast, other Finnish experts argued that this move to the large cities undermined the traditional Finnish way of life and was anyway environmentally less sustainable.

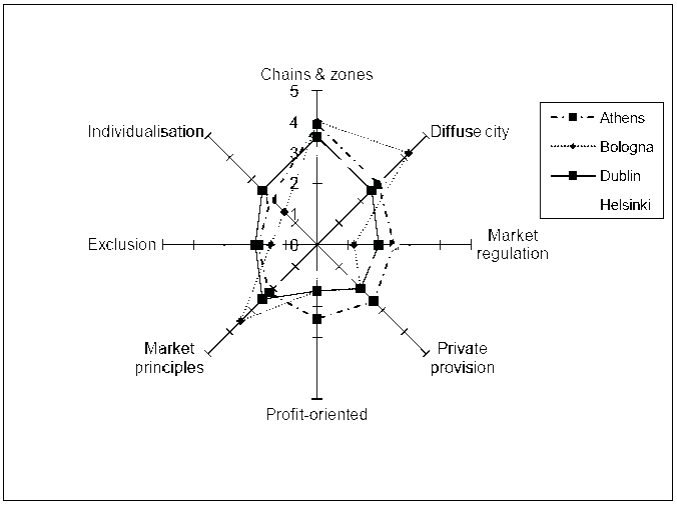

Figure 3. Experts' desired scenarios

In terms of the 'institutional aspect' of transport provision, all the groups stressed the role of the state and of public control and regulation. In Helsinki, where there was already some experience of limited competition on the bus lines, the group argued that regulation and market mechanisms can be combined and are not necessarily antagonistic. This was the clearest acceptance of some role for the private provision of 'public' transport. Here however the group insisted that overall public control was crucial, and that this had to involve public control of physical infrastructure. While this debate over the institutional structures for public transport has become commonplace recently, it is noticeable that nowhere among our groups was there a strong demand for more private provision.

The debate amongst the experts also raised two issues that are not usually heard in the conventional discussion, dominated as it is by the categories of economics or engineering. In Bologna participants stressed that public transport was 'public' in the sense of sociability – travelling by public transport allowed you to meet people, it was part of living in a city with fellow citizens. This rather understated connection between public transport and public citizenship was also developed by participants from Bologna and Helsinki, who talked of the importance of 'moral pressure' in getting people not to use cars. It both senses therefore public transport is seen as something belonging to the public realm, not as simply a technical solution to a given mobility need. Presumably this understanding of the public nature of public transport is difficult to reconcile with its private provision.

Significantly, there was universal support for financial subsidy of public transport. All experts accepted that public transport would require public subsidy, with the Finnish group in particular stressing that the reason for this was essential to ensure accessibility was available to all. Even amongst those directly concerned with the actual provision of transport in cities, there was clearly no discernible strong desire for private enterprise participation and deregulated solutions which were already being widely promoted by some national governments and the European Commission. Furthermore, even in the two cities where state owned public transport has been a manifest failure, namely Dublin and Athens, there was no strong pressure for outright privatisation and marketisation.

The two 'societal' dimensions are 'individualisation versus social cohesion' and 'exclusion versus social inclusion'. Here all the experts opted for social cohesion and social inclusion. This is hardly surprising, since almost by definition everyone is in favour of social cohesion and social inclusion! This is the sort of position can only be explicitly rejected by a clearly formulated neo-liberal ideology which regards inequality as desirable in itself and which values individualism so highly that it is prepared to tolerate high levels of social anomie. Such an ideology remains unusual in Continental Europe, unlike in the USA. Clearly most participants regarded social inclusion and social cohesion as linked, although interestingly in the Helsinki discussion it was suggested that social inclusion is the basis for individualisation of the full development of each individual's potential.

As far as the layout of the cities themselves was concerned, all the experts were opposed to European cities developing as suburban cities on the US model. However, there was disagreement in each group as to the extent to which their city should become 'compact'. Thus in Helsinki, some felt that making the city more compact would mean a loss of green space and be 'unjust' or even 'unhealthy'. In Dublin one participant argued that:

> I believe we could be living in a compact, dense city; a post-industrialised city, in a civilised city that is clean and efficient. I don't believe we are going to (Dublin focus group participant)

We will return to the issue of 'not getting what we want' later, but it is important to notice that this view was not shared by all the Dublin group:

> I think we don't want to have a tightly focussed European city where the centre is very dense. I think we are

likely – just looking at the character of Dublin city as it is – we are likely to have a more diffuse shape and I don't necessarily think there is anything wrong with that. In my housing estate, for example, there is a huge big green pitch for kids to play football. I am not a believer, personally, in the European model of apartment living, which is often held up as the great way to do cities. I think it might be good from a transport point of view but not necessarily from a society point of view (Dublin focus group participant).

By contrast this notion of the European city was supported unanimously in the Bologna group. For them the city centre was an important source of identity for the citizens, as well as a place for recreation and if possible for habitation. This meant that for the Bologna group, the city as a whole should remain compact, as the Bologna report stated, in what is effectively a summary of sustainable mobility:

> In the experts' desired scenario, the city is an accessible, socially compact and liveable place, where the car becomes a residual means in the economy of mobility (Bologna scenario report).[6]

4.2 Experts' expected scenarios

Turning to the future of their cities, the experts were mostly pessimistic. Whereas their desires tended towards the centre of the 'web', their expectations (with the exception of 'concentration' versus 'chains & zones') tended towards the rim. Interestingly, the Dublin experts were the most pessimistic of all the expert groups (Figure 4).

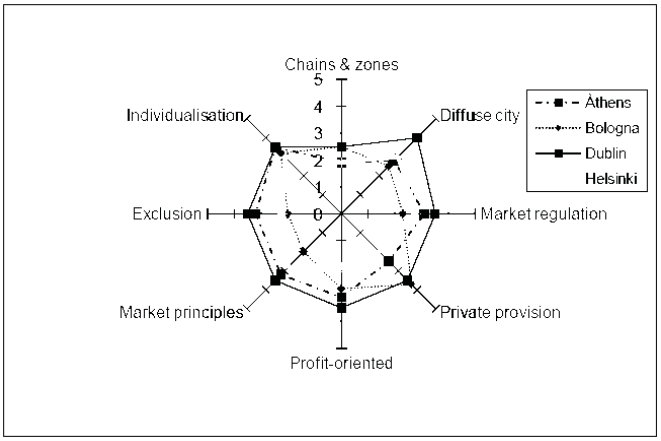

Figure 4. Experts' expected scenarios

In terms of spatial developments, all the experts expected population growth to be concentrated in the main urban regions, even if they would have preferred a more evenly distributed growth.

Rather similarly, the experts all expected a move towards more regulation through market mechanisms and more private provision of transport. Here again the Dublin experts took the most 'extreme' position. Our measuring instrument does not really measure the extent of change from the status quo. The comments however suggest that in both 'worst case' Athens and 'best practice' Helsinki, the experts expected very little actual change, so that state regulation would continue to be more important than regulation through the market, and public transport would continue to be largely provided by publicly owned enterprises. By contrast, in Bologna and especially in Dublin the experts anticipated a substantial shift towards market regulatory mechanisms and the private provision of public transport. None of the experts' contributions suggested that they anticipate any major benefits from these changes, and in the Bologna discussion it was suggested that they would create greater problems of co-ordination.

As we have already seen, the experts frequently found the dimension 'organisation of the European economy' outside their area of competence and not really relevant to transport issues. In terms of the subsidisation of public transport experts in Athens and Bologna in particular stressed that public transport would always need subsidies, no matter how it was organised.

Most experts anticipated a future of greater social inequality with social welfare systems becoming less redistributive. In Athens the experts expected the effects of the growth in social inequality would be softened by the continued importance of the family, thus echoing social policy

[6] The Bologna experts' score of 4.2 on this dimension indicates a desire for a very diffuse city, but this seems to be contradicted by their comments.

writers who have suggested that the family lies at the heart of the 'Mediterranean' version of the European welfare state (Ferrara, 1996). At the same time however the Greek experts foresaw a growth in individualism and a diminishing regard for the common good. In Bologna too a similar theme emerged. Although the experts there foresaw that in the future the social welfare system would continue to restrain social exclusion, they worried that conventional mass participation in politics would continue to decline and that the social welfare system would becoming increasingly disconnected from new forms of politics and less able to tackle new forms of social exclusion. The comments from the Helsinki group were rather more optimistic. They were aware of growing inequality and growing individualisation; and they suggested that both changes were symbolised by the growth of gated communities of new housing. Nonetheless, their optimism derived from the fact that they did not expect such forms of physical and social withdrawal to become normal.

Turning to the compact city issue, the dimension we have directly linked to sustainable mobility, only the Dublin experts expected an extensive suburbanisation of their city itself. The reasons for this varied. In Bologna relatively compact cities were seen as inherent in the Italian way of life

> There isn't the English or American mentality that you work until Friday evening and you stay at home with your wife and children on Saturday and Sunday. In Italy, there is the custom to return to the centre to have access to services, cinemas, restaurants etc. This leads me to believe that there is an alternative to this expansion, in other words, people move out of the city because they are forced to because of conditions but if they can, they stay in an acceptable area in the centre (Bologna focus group participant).

In Athens high density would continue because the infrastructure was inadequate for more dispersed settlement, and only in Helsinki would this happen as the result of planning policies. It is often argued that cities land use policy should promote higher density in cities *in order to facilitate public transport.* Paradoxically however, our scenarios do suggest that some of our cities will remain relatively compact, but not, according to our experts, because of any closer linkage between land use policy and transport policy.

5 EXPERTS AND TECHNOLOGICAL STRATEGIES

As well as completing the 'spider's web' scenarios, the experts also discussed various transport technologies and the extent to which they saw them as *desirable* and the extent to which they *expected* them to be used. It is important to notice that these are discussed as 'technologies', i.e. outside of any specific institutional structure (such as discussed in the scenarios) and without any explicit discussion of costs. Some technologies (physical infrastructure, whether road or rail) would have a high capital cost as well as running costs, all of which would probably have to be subsidised by the state in some form. Other technologies mainly impose actual costs on car users (e.g. parking fees or road pricing) or physically restrain them (e.g. bus lanes). Finally the new technologies (e.g. electrical vehicles) provide alternative transport means within a system which is still based on individual mobility.[7]

Repeating the form of analysis used for the scenarios, Figure 5 presents the technologies experts wanted introduced and those which they expected to be introduced.[8] Although roads and rail infrastructure both involve costs, it is noticeable that the experts clearly preferred expenditure on rail systems. The three rail technologies all scored higher than any other technology apart from the new vehicle technologies. However, while the experts did not see roads as particularly desirable, they nonetheless expected them to be built, while conversely they saw rail systems as desirable but less likely to be actually built.

[7] Obviously this is a simplification. Subsidies to roads (and cars) operate in different and less transparent ways than subsidies to public transport. Alternative forms of private transport may well involve different forms of private mobility – for example, if electric cars have a shorter range and lower speed, they would be less compatible with suburbanisation than existing cars.

[8] Desired scores were reported for all four cities; no 'expected' scores were reported for Dublin. However the Dublin report states that while the Dublin experts favoured rail-based technologies over the construction of more roads, they in fact expected more expansion of roads than rail. Dublin 'expected' scores would not therefore undermine the analysis of this section.

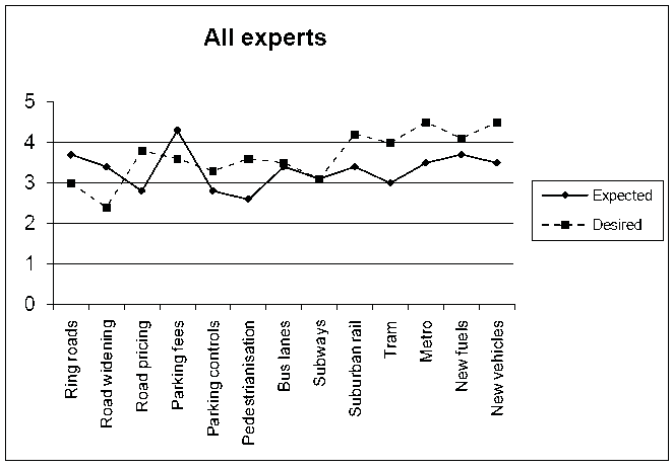

Figure 5. All experts' expected and desired technologies

By contrast for regulatory measures (bus lanes, etc.) the experts' aspirations appeared more realistic. Experts wanted some increase here, and this in line with what they expected to actually happen. Of the market measures, parking charges got a higher 'expected' than 'desired' score, whereas the reverse was true for road pricing and reducing parking supply. Arguably the experts wanted measures taken which would actually reduce car usage, but suspected that these measures would merely be introduced to raise revenue.

5.1 Experts' desired technologies

Figure 6 presents the experts' desired technologies in the four different cities. It shows that the key finding of the aggregate level analysis remains true at the city level: in each city experts were in favour of rail-based solutions and less favourably disposed towards road-building. There are however some differences between the cities on this and other technologies.

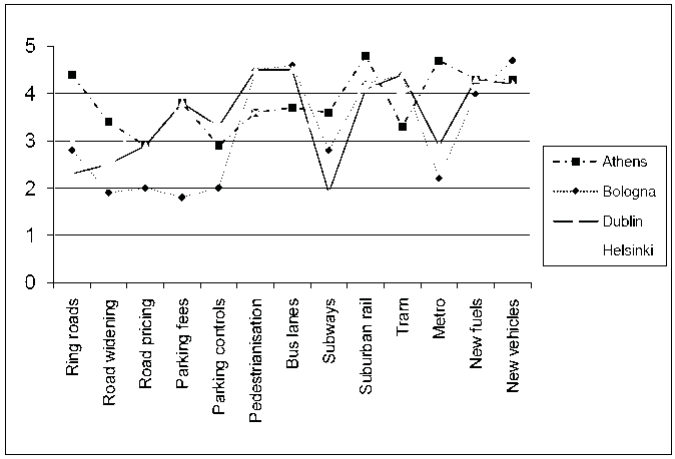

Figure 6. Experts' desired technologies

In terms of road building, Athens was unusual. Much more so than their colleagues elsewhere, the Greek experts were strongly in favour of ring roads and even supported road-widening within the city. The very limited construction of new roads in Athens before the construction boom of the Olympics was not because of any political decision, but because of general institutional problems. At the same time, streets were already filled with cars. In many other European cities it was already the conventional wisdom of transport specialists that road building merely generates more traffic, but this had little intuitive appeal in Athens. At the time of the research Athens had not had the negative experience of other cities, where new roads have destroyed the inner city without solving the traffic problem. In Athens the city was being destroyed - not by new roads, but by cars clogging existing roads.

There is also a divergence on the desirability of a metro system. Metro extensions scored highest in Athens and Helsinki, both of which already had a metro. By contrast, building a new metro received rather low support in Bologna and Dublin, neither of which had a metro at the time. The Bologna result can plausibly be explained in terms of the unsuitability of a metro for what is the smallest of our four case study cities. By contrast, even by 2000 detailed plans for a metro in Dublin had already been discussed for decades, but the metro was largely posed as a partial alternative to on-street rail, not, as in Helsinki, as a complement to it. Interestingly, in Athens a tram system had been mooted as an alternative to an extension of the metro, but the experts give the metro the higher rating.

In terms of the desirability of controlling car usage, Bologna emerges as the outlier. Although Bologna was one of the first Italian cities to introduce controls on cars, by 2000 the experience had become increasingly negative. Traffic control in Bologna had become widely seen as simply a restriction on citizens' wishes, rather than as part of a new and improved mobility for all. The Bologna reports also lead to the suggestion that restrictions on car usage should involve some appeal to social citizenship or 'social capital' – an asset that appeared to be declining in Bologna.[9]

[9] Another term for social citizenship could be 'social capital' (Putnam, 1993). It is paradoxical that the term was introduced into social science by Robert Putnam in his study of civic activism in North-Eastern Italian cities – such as Bologna!

Finally it is worth noting that pedestrian subways are often viewed negatively - as dangerous and unattractive spaces - while new vehicle and fuel technologies appear as self-evidently desirable to all.

5.2 Experts' expected technologies

Disaggregating the experts' expected technologies shows that within each city it was still true that expectations for road building were higher than for rail infrastructure (Figure 7). In Bologna scores for both forms of road building were higher than those for all rail forms; in Athens the only exception to this is the metro (doubtless partly because the metro is at the moment the largest transport project within the inner city area). Only in Helsinki did rail projects come very close to road-building, and in Helsinki too, all three forms of rail infrastructure scored highly. In the experts' expectations therefore, Helsinki came closest to moving away from merely continuing to invest in the existing car system. Finally it should be noticed that Helsinki is also remarkable for the extent to which all technologies received relatively high scores – in other words, the experts in Helsinki expected their city to be implementing a broad range of measures to improve mobility.

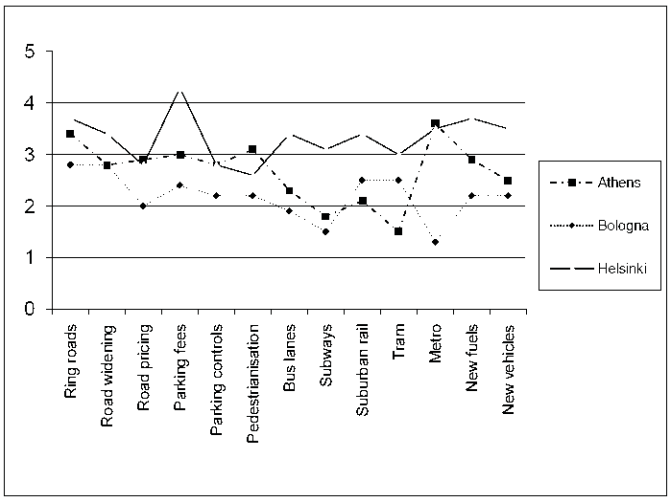

Figure 7. Experts' expected technologies

6 EXPECTATIONS IN CONTEXT

These interviews suggest that already by 2000 European urban experts had become advocates of what Bannister later termed the sustainable mobility paradigm. They preferred the expansion of public transport in all its forms over continued road building. Indeed, only in Athens was there any real support for any new road projects at all. While they accepted that private cars would continue to be important, they hoped to see the introduction of more environmentally friendly vehicles and fuels. Crucially, while they supported measures to directly restrain car usage (road pricing, parking fees, parking controls), they considered all forms of rail-based public transport to be more important. Turning to the spatial planning aspect of the paradigm, the experts were fundamentally committed to the idea of the compact city and often identified this as a specifically *European* model. Our interviews suggest therefore the emergence of a clear European policy consensus in support of sustainable mobility and furthermore, that this is defined in broadly the same way across Europe.

Furthermore, urban experts did appear to see sustainable mobility as linked to an important role for public authorities and the state. Although they gave importance to market principles in the general organisation of the European economy as a whole, they clearly wanted public transport to be subsidised and were somewhat sceptical of the effectiveness of private provision and of regulation through the market. The Finnish experts were the only group with experience by 2000 of the private provision of public transport (recall that Helsinki's bus routes were already provided by private companies). While their experience had been positive, they stressed the importance of overall public direction and regulation. Finally, this stress on the role of the state went together a desire for greater social inclusion and for some restraint on pure individualism. Transport, for these experts, did seem to be implicitly part of what I have elsewhere termed 'the European social model' (Wickham, 2002; Alber, 2010).

If our experts wanted sustainable mobility, they were however not very optimistic that it would be achieved. They expected road building to continue more than they would hope, and public transport to be expanded less than they would desire. Although they were more hesitant, they also expected suburbanisation to continue. For them, the compact European city might be an ideal, but the reality lay more in the past than in the future. They expected institutional developments to favour private provision and regulation through the market. Here however there was an important divergence between the concerns of these urban experts and those of many urban transport policy makers. Although the dimensions of the scenario building exercise focused strongly on issues of market versus state regulation and provision, such questions did not particularly concern them.

Privatisation, deregulation, competitive tendering for public service contracts – all the institutional innovations that were already attracting much attention at national and EU level – all played relatively little role in the open-ended discussions. In other words, such 'solutions' appeared to these experts at least as at best marginal and at worst irrelevant to actually tackling the transport issue in their cities. And finally, the experts saw the broader social context in gloomy terms: they might desire more social equality and more social capital, but what they expected was a society of greater inequality and greater individualism.

There were also significant differences between the experts. These confirmed and illuminated the systematic differences between the four cities that emerged elsewhere in the research. In the study as a whole Athens and Helsinki were our extreme cases, respectively the 'worst' and the 'best' cities in terms of car usage and car dependency. In these two cities the experts' aspirations and expectations were relatively close to each other. In Athens the situation was so bad that our experts' aspirations appeared to have been lowered in line with their expectations, while in Helsinki the experts' aspirations were really for minor improvements within what they considered already a reasonably adequate status quo. By contrast, in both Bologna and Dublin the situation appeared much less stable. In Dublin, the experts' aspirations diverged dramatically from their expectations, suggesting a pent-up frustration which perhaps reflected the contrast between the ambitious plans of the key transport authority (DTO, 2000) and the reality of congested roads and inadequate public transport. In Bologna, the experts looked nervously into the future, expecting an erosion of the political structures that had sustained the city's pioneering initiatives in the past. We now turn to evaluating these expectations.

The original research project originated in the belief that the current levels of car usage in European cities were a major threat to environmental sustainability. However, we deployed our competence as social researchers not to investigate this issue directly, but to ask about the possibilities and implications of change. The car is central to contemporary life: realistically, how could a reduction in car usage be achieved and what would be the social implications?

The scenarios provided one starting point. The experts' aspirations and expectations, provided evidence as to the possibilities of change. The first part of this paper suggested that motorisation was partly halted in some cities in Europe during the 1970s. Of our two case studies, both Helsinki and in Bologna experienced 'switching points' in the late 1960s and early 1970s: the first pedestrianisations in the Centro Storico and the experiments with free public transport in Bologna, the rejection of the Smith-Polvinen urban motorway plan in Helsinki. These social movements were part of a process which moved these two cities decisively away from continued fordist car dependency. However, such changes are not necessarily permanent. For example, also in the 1970s social movements helped to halt a massive programme of urban motorways in Melbourne. However, in recent years there has been a revival of large scale road construction in the city, financed by public private partnership and linked to a new ideology of urban growth and competitiveness (Davision, 2004).

In terms of transport technologies many of the experts' pessimistic expectations have *not* been realised. The expansion of rail-based transport has been on the policy agenda in each of our four cities. The most dramatic case has been Athens. By 2010 the city had restructured suburban rail lines and integrated them with an entirely new tram system and a vastly expanded metro. By the same year our other worst case city, Dublin, had two (unconnected) light rail lines and improved suburban rail including several new stations. In Helsinki there had been some minor extensions of the tram system, some enhancement of the metro, and work had started on the long debated major extension of the metro to the western city of Espoo. Only Bologna saw no extension of rail transport within the city, although discussion of a new light rail line centring on the nearly completely rebuilt mainline railway station does continue. In all four cities, as elsewhere in Europe, there has been a clear trend to maintain and improve the city centre as a leisure and tourist destination, what has been called 'museumification' (De Frantz, 2005), and this does require improved public transport. Dublin and Athens also saw additional restraints on car usage in the city centre, even though Dublin's historic College Green continues to be a traffic intersection (albeit with bus lanes).

Nonetheless, facilities for the motor car have also been enhanced. In the immediate environs of all four cities motorway construction has continued (e.g. completion of the Helsinki-Turku motorway and an entire inter-urban motorway network in

Ireland). Within the cities there has been the construction of massive urban motorways in Athens and of the Port Tunnel in Dublin, although especially the latter has been justified on environmental grounds as taking traffic out of city centre.

In terms of spatial planning the experts' worst expectations have been fulfilled. Everywhere urban sprawl has continued, with Dublin leading the pack. Indeed, Dublin's sprawl was highlighted as an example of bad planning by the European Union (European Environmental Protection Agency, 2006), and this before the final splurge of the Celtic Tiger. As we have seen, the compact city is a core component of the sustainable mobility paradigm. Sprawl is usually measured simply by population density, yet the link between density and car usage is not actually straightforward. On the one hand, some Scandinavian cities, such as Helsinki but also Copenhagen, have low overall density but effective public transport, largely because development is clustered around public transport nodes. On the other hand, car usage is rising in high density cities such as Athens, just as it is in newly affluent but compact cities of Asia.

Reviewing the evidence to date a preliminary assessment is that by 2010 there had been no major shift away from car usage and indeed car dependency, with the possible exception of Athens. Of all four cities, Athens had appeared most clearly locked into its original trajectory, but partly because of the 2004 Olympics a series of major infrastructural projects have transformed public transport provision (extensions to the metro, reconstruction of the suburban rail line, a new tram system). In addition, institutional changes have improved the integration of the public transport system. Nonetheless, these prestige projects have made relatively little impact on overall levels of car usage.

Bologna turns out to be the most negative city from the perspective of sustainability. Having once stood at the forefront of transport change in Europe (Jaeggi et al, 1977; Topp & Pharaoh, 1994), the city appears to rejecting the trajectory of the last thirty years. This was in fact in line with the findings of our scenario exercise. The discussion suggested that a growing individualism, allied to political changes, had already begun to undermine the collectivist (and rather 'top down') solutions of the previous generation. The measures needed to directly control car usage were seen as particularly unlikely to succeed in Bologna. Although in the scenario discussion the experts were clear that the Italian preference for relatively compact cities would persist and an important role for the state would continue to be important, Bologna appeared as a city where car dependency could well be *less* controlled in the future. These predictions have been borne out. Bologna in fact is the only one of our four cities in which there has been no expansion of public transport infrastructure in the last ten years.

The remarkable feature of the Dublin scenario-building was the experts' dystopian vision. While those involved in policy formation argued for radical solutions (a very compact city with a strong reliance on rail transport), they were pessimistic as to whether such solutions would be implemented. Shortly after our meeting, the body charged with developing a transport strategy for the city published its proposals for the period until 2016: whereas in 1997 73% of all journeys to work in the Dublin area were by car, it was planned to reduce this to only 37% in 2016 (Dublin Transportation Office, 2000). While it is indeed noteworthy that such radical plans were being formulated in Dublin (Ellis and Kim, 2001), in 2010 such a change now seems totally implausible.

Finally, the Helsinki situation suggested the traditional maxim 'If it's not broke, don't fix it'. Throughout the project Helsinki consistently emerged as a best practice case, with the highest levels of public transport usage and low car usage and low car dependency. This despite the fact that the institutional structures were the more market-oriented options in the scenario. The discussion during the scenario building continually raised the linkage between citizenship, public spaces and public transport, all centred around a positive evaluation of powerful local government. Indeed, Helsinki is the only case of all our cities where public authorities had clear plans which they appeared to have a realistic chance of implementing.

7 CONCLUSION

By the year 2000 many urban experts across Europe accepted what has been termed the sustainable mobility paradigm. As we have seen, in our four cities experts expressed a clear preference for investment in rail-based public transport over further road-building; they favoured restraining car usage; they hoped to limit urban sprawl; for them the European city was a compact city. Sustainable mobility thus involved both technologies of mobility in the broadest sense and spatial planning.

For these experts, sustainable mobility was linked to a strong state, restraints on social inequality and extensive social cohesion (social capital). For them, as for enthusiasts of the 'European Dream', environmental sustainability was interwoven with social structure in a distinctively 'European' way (Hill, 2009; Rifkin, 2004).

Yet our experts did not expect such aspirations to become reality. The gap between aspiration and expectation was lowest in Athens and Helsinki, but for very different reasons. In Athens aspirations were not quite so clearly within the framework of sustainable mobility as elsewhere, and so were more consistent with the anticipated (and less sustainable) future. Only in Helsinki did experts anticipate that their aspirations towards sustainable mobility might be achieved. By contrast, in Bologna and in Dublin, experts looked to the future with trepidation. They anticipated a move away from sustainable mobility and they linked this to (to them) undesirable changes in social structure and political institutions.

In fact in relation to technology per se our experts were perhaps over pessimistic. The worst case city, Athens, saw a massive expansion of rail-based transport, while rail was also expanded in Dublin. Unlike in the USA, some rail transport is increasingly the norm in European cities. However, what is less obvious is that road building and motorisation have also continued, so that sustainable mobility technology is probably further away than ten years ago. In relation to the spatial planning aspect of the paradigm, here too the gap between aspiration and reality has probably increased. In our four cities, but especially in Dublin, our experts' gloomy (to them) expectations have been fulfilled: the compact European city remains an ideal of the past rather than a realistic aspiration for the future.

For some researchers this is hardly surprising. They consider that urban sprawl is the inevitable outcome of greater individual mobility, itself an inevitable result of greater individual choice resulting from economic growth. Accordingly, sustainable mobility has to mean more environmentally friendly technologies above all electric vehicles (e.g. Rienstra and Nijkamp, 1998). Yet such arguments ignore the sheer variation of urban form and urban transport within Europe. At its most extreme, a few cities such as Munich and Bilbao with very good public transport and strong urban government have been able to limit sprawl (EEA, 2006); cities such as Helsinki and Copenhagen have an overall low population density but their spatial planning and extensive public transport make mobility more sustainable.

The claimed inevitable domination of the automobile also ignores the linkage between sustainable mobility and social structure in its broadest sense. Our experts were challenging fordist automobility, where the private car is facilitated by massive expansion of publicly funded roads. Today the family car is as outmoded as the family telephone: the car, like the mobile phone, is individualised. The infrastructure which promotes this automobility is increasingly privately financed through various forms of 'public private partnerships. Just as our experts linked sustainable mobility to other features of European society, so new forms of automobility appear to be linked to the erosion of European social structures by financialisation and individualisation, to the destruction of public facilities and public spaces by an expanding market. In this increasingly unequal society, urban ideals become the leisure ideology of the affluent, but for much of the population, the car and its unsustainable environment remains an essential, if expensive, necessity. In far away Melbourne too the car wars of the 1970s have led to a new defeat in victory:

> Walking or cycling to work from a warehouse apartment, drinking caffe latte in a sidewalk café , sociability rather than seclusion are the new urban ideals. Now it is the poor, marooned in far suburbs, who are most dependent on their cars, and most vulnerable to the rising costs of urban sprawl' (Davison, 2004: 261).

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MANAGING CAR DEPENDENCY: REVIEW OF WORLD CITIES EXPERIENCES AND LESSONS FOR THE UK

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ABSTRACT

Car dependency is a critical issue facing towns and cities across the UK. Recent rises in car ownership combined with stability in the patterns of their use (Vkms) is a crucial policy issue which requires attention in the development of an adequate policy response. City structure, land use patterns, urban densities, socio-economic characteristics, ample parking spaces, low investment in public transport service provisions and its limited use are the key factors for increased car journeys in cities. The spatial changes combined with rapid growth of car traffic have adverse effects on the environment, road safety and health. Responses to make car less attractive by levying high taxes on car use, encouraging alternative transport modes, mixing of land uses and traffic management measures have been effective in many world cities. The paper explores various policy measures implemented internationally to manage car dependency. The review of policy responses identifies the range of experience in terms of transport and development strategies to control car usage and ownership. Furthermore, an assessment of car dependency nature and policy approaches adopted in UK rationalise the policy objectives, examine adequacy of the available policies and lessons from international experiences to limit car use in cities.

Keywords: Car dependency, Policy, Transportation, Cities.

1 INTRODUCTION

Sustainable transport options for the city have become a key issue in delivery of an effective transport policy for cities. In last few decades, the car use per person has risen significantly across the Europe and Asia (Kunert, 2007; Kenworthy, 1999). Responding to the trend, car has dominated other transport modes across the UK (RCA, 2009). The radical shift in the life styles, increased income levels, improved economic opportunities, and increased participation in social and leisure activities has resulted increased car trips in cities (Abrahamse et al, 2009; OECD, 1995). People are now heavily dependent on cars for their scheduled (essential) and occasional journeys due to the advantages of time, convenience, privacy and until recently cost. This preferential choice of car use has led to increased levels of car dependency. Economic, social and environmental costs associated with rising car journeys have challenged the allocation of resources to development activities and the environment. Policies aimed at the reduction of car dependency and an increase in the role and mode share of public transport, are high on the world's political agenda to satisfy demands for sustainable development and climate change objectives (CBT, 2009).

In early 1950,s world population was 2.6 billion with 50 million cars on the roads (Newman et al, 2008). In 2000, the population numbers crossed 6 billion (UNFPA, 2007) with massive increase in automobiles approaching 500 million. This growing car ownership and its habitual use in last six decades have threatened the sustainability of urban areas. Recently, the world population have reached 6.7 billion (2008) with half of the population living in urban areas driving 600 million cars on world's roads

(www.lowcarboneconomy, 2010). With current growth in car traffic, it is expected that number of motorised vehicle will cross 1 billion by year 2050 (Gauzin-Müller, 2002). Past and present trends of transport supply dominated by private automobiles are challenging the policy makers not only to manage growth of cars in world cities but also to safeguard against the impacts of environmental damages, accidents, road congestion and high fuel consumptions.

Recent rises in car ownership combined with stability in the patterns of their use is a crucial policy issue which requires attention in the development of an adequate policy response. Dispersed development patterns, increased land values in the core city, raised income levels, social changes and household's travel behaviours are the key factors for increased travel demands within urban areas (kenworthy, 1999). Cars are being identified as the most space intensive mode of urban transport (Crawford, 2002). The benefits associated with the car use (high speed, door to door access, multiple choices, privacy and safety) have resulted in an expansion in car use (Moriarty, 2008). The shift in travel behaviour away from more public modes of transport has caused social, economic, environment and management problems. As a consequence, increased carbon emissions, higher noise levels, fuel demands, congestion, space demands and road accidents are threatening the urban quality of life (Mayer et al, 2007). Moreover, people who do not own a car have been socially excluded to access particular shopping, leisure and employment locations in a city (Steg, 2003).

The disadvantages of car dependency are apparent within individual and groups, but still car use is rising in most countries including UK; whilst government objectives to reduce car dependency and promote sustainable transport modes (DfT, 2005e & 2008g; Goodwin, 1994; RAC, 1995). The UK is facing challenges to manage transport system in cities that is heavily dependent on cars despite difference in their city structures and transportation patterns (CfIT, 2007). An increase of 28 percent in the car ownership has been experienced from 1994 to 2004 in the UK (Clark, 2009). The major factors contributing to the increase in car ownership are household income, size and composition. The statistics for the National Travel Survey for low income households reveal that cars are used for 45 percent of the daily household trips and accounts for 65 percent of total travel mileage. More than one third of households own a single car and 70 percent of adults have driving license. The current research study indicates that use of a car is more frequent for leisure trips (RCA, 2009).

Growing car use is a strong barrier to achieve sustainability objectives in world cities. Recognising the fact, many cities are attempting to attain mode shift objectives by restricting car ownership and use. The informed policy measures, such as traffic calming, pedestrian and home zones, road pricing, multi-modal public transport system, travel demand management, behavioural changes, parking controls and increased share of walk and cycling in daily travel attempt to minimise the impacts of growing car reliance in many world cities (CfIT, 2005). Given the fact that many UK towns and cities facilitate private motor cars at the direct expense of public spaces and other city features; the review of car dependency nature and response of various policy measures within international cities is crucial to explore transport policy options for the UK.

2 RATIONALE OF THE PAPER

The extent and nature of car dependency problem is different in the world cities depending upon the rate of car ownership, availability of transport infrastructure, diversity in pricing policies, significance of public transport network in their usage and the land use transportation interaction, government investments and priorities, socio-economic factors and household travel behaviours. The paper describes common trends and nature of car dependency (vehicle ownership, vehicle use, quality of public transport and use, share of public transport in motorised travel and mode split) within international cities, compares transport policy objectives and measures implemented, and appraise success of strategic interventions in delivering policy targets to manage transport demands and restricting car use. The lessons from international experiences to control and manage car dependency in urban areas have been reviewed as a knowledge contribution towards development and delivery

of sustainable transport policy objectives (reducing car dependency) across the UK.

3 LITERATURE REVIEW

3.1 Land Use pattern and car dependency

The amount of travel in a city is assessed by parameters of travel behaviour and spatial planning (Souche, 2010). Many researchers believe that intensive spatial changes in the planning of existing and new developments with limited improvement in transport infrastructure and services have altered the movement patterns, transport demands and mode choices of the people. These changes in the spatial patterns of cities have resulted in high ownership and use of the private cars (Sinha, 2003). The research studies result indicate current decentralisation trends in most European cities as a major cause for growing car ownership across the Europe and UK (Hansen, 1993, Gillespie, 1999 & Giuliano, 2005). The research and development theories on this particular topic consider urban density as a most influencing indicator affecting the pattern and patronage of the urban transport system in a city. Higher residential densities "*Compact Development*" having mixed type land uses and reduced trip lengths encourages the viability of public transport operations, walking and cycling modes while "*Dispersed Development*" tends to separate activity areas by large distances and are attractive by private motor car journeys as long as public transport network is not available. Therefore, the existing land use patterns of a city defining locations and distances amongst work places, shopping areas, schools and neighbourhoods have significant value in assessing amount of travel, journey patterns and movement behaviours impacting people's decision to own and use a car for daily travel needs.

3.2 Factors influencing car ownership and use

The research studies indicate that decision to own a car at individual level is medium term in nature influenced by variables of residential location and employment places (Naess, 2006). The variation in patterns of car use is associated with the parameters of age, gender, geography and income levels of the population. The other important parameters are the availability and quality of public transport, transport infrastructure and trip cost. All these factors combine together in arriving at the decision by individual or household to use a car (Acker, 2010). In older parts of many cities, local shops and services have been shifted away from neighbourhoods due to regeneration policy previously accessible by walking to long distances for which local people started to travel by cars to benefit from those local services, thus increasing traffic volumes on neighbourhood streets (CBT, 2009). Most recently, the development patterns of new housing locations planned without expanding public transport networks are responsible for car oriented developments. The increase in the economic status and wealth of a family also give rise in private car usage for essential and occasional journeys. The rise in per capita income decreases the relative price of automobile travel and people find private cars more attractive due to high speed and time savings (Ingram and Liu, 1999 & Giuliano, 2005). Ingram and Liu, analyse the relationship between the income elasticity of demand for private cars, and their use. The study results indicate that car use increases with rise in the income despite variations in the elasticities. The research also observed the income elasticities of motor vehicle use less than one which are smaller than the long-run income elasticities of motor vehicle ownership, suggesting that motor vehicle use increases less rapidly with increases in income growth than motor vehicle ownership does (Kain, 2001).

Given the relationship between fuel prices and car use, it was observed that the fuel prices have an elastic demand and use of private cars would decrease with increase in the fuel price (Hanly et al., 2002; Holmgren, 2007). Use of public transport is more elastic to fare variations and decrease in fares would increase patronage of public transport (Paulley et al., 2006). The change in prices effect the travel demand and use of particular transport mode. The demand for the private cars will be substantially increased with decrease in the user cost or increase in household income and waiting times for public transport (McFadden, 1974). Similarly, the demand for public transport increases with decrease in waiting time, fares and improved service quality of public transport against rise in cost by car travel (Souche, 2010).

3.3 Impacts of car dependency

The global impacts of car dependency are on the energy cost and green house emissions. The local impact of automobiles dependency in cities of Australia, Europe, USA and Developing Nations are emissions, noise, gridlocks on roads and spaces wasting precious hours and destruction of natural landscape (Newman, 2006). Other problems like social exclusion of certain groups of society who doesn't own a car and isolation of the suburban areas are also an outcome of the automobile dependency (Steg, 2003; Kenworthy, 1996).

Car dependency is, however, a major threat to sustainable transport initiatives (Han, 2010). People are increasingly cognisant of the damaging impacts of the car traffic on the built environment and quality of life (Newman, 2006). The international responses to increased car dependency are the ongoing development and implementation of fiscal policy measures, road pricing schemes and strict parking controls. Growing policy concerns with climate change, social exclusion, energy consumption, sustainable transport and public health have forced the government to address the challenge of car dependency at their national and local levels. The transport sector is a major contributor to CO_2 emissions and shares one quarter of the carbon emissions in the UK (Hickman, 2010).

The impacts of car dependency are evident in the form of large concentration of parking demand in the business areas of cities, major employment centres, commercial and retail facilities and leisure areas. Allocation and management of parking space in those highly car concentration zones are tough decision for the authorities whilst to high land values in central city and demand for offices and real estate market potentials. The construction of multi-storey car parks in those locations creates visual impact on city image and streetscape; while on-street parking creates congestion by reducing road capacities (Steg, 2003). The decline in public transport patronage is also an outcome of growing car dependency in many urban areas as public transport service operators tend to reduce their frequencies during off-peak hours (Cairns, 2000).

The commuting into the central areas of towns is connected with problems of time, cost, congestion and inconvenience due to increased car dependency (Pooley, 2005). The negative effects of car dependency have threatened the metropolitan cities of the world. Recognising the role of transport policies and strategies to respond the global sustainability targets of low carbon economies, the impacts of increased car traffic are the major challenge (Kenworthy, 1996).

4 CAR DEPENDENCY IN THE UK

4.1 Historical perspective

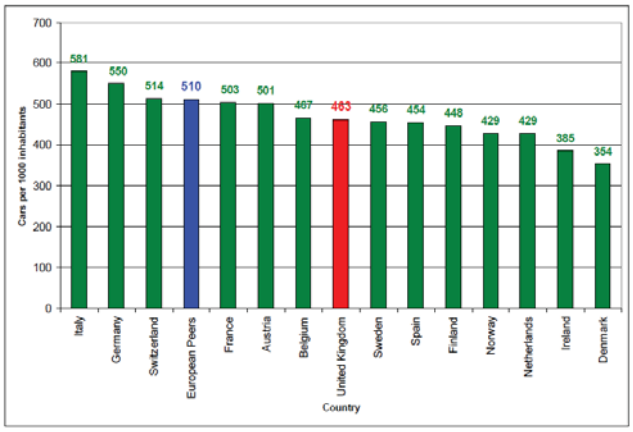
After industrial revolution and before 1920s, the 40 percent trips to working places were carried by walking in the British cities. During 1920 to 1950, public transport remained major transport mode facilitating the movement of people within urban areas and working places with some proportion of population travelling by bicycles and walking (Headicar, 2009). Till 1940, the use of private cars was limited only to leisure trips; however after 1940 trends to approach the work places using private cars started to gain momentum among males. Suddenly within few decades, car became dominant mode of travel for all kinds of trips (Pooley, 2000). Meanwhile, government also heavily invested in new road infrastructure encouraging private automobile travel. The car use was not frequent till 1980s among females in British society and later on share of car trips among female especially working women rose rapidly leading to decline in the use of walking, cycling and public transport (Pooley, 2005).

The negative impacts of time, delays, cost, health and environment from car traffic got attentions of the government in 1960s, but no major actions were taken arguing economic development and managing transport demands as dominated motives compared with neighbourhood planning and sustainability. In last decades of the 20th century, the global agenda of low carbon cities to restrict high level of green house emissions pressurise the government to pay attention into the development of sustainable communities with reduced car dependency in cities (Pooley, 2005). In response, the government announced transport policy prioritising actions to control carbon emissions, limiting automobile stock, encouraging integrated transport system, reduced

journeys and high patronage of public transport, walking and cycling modes.

4.2 Reasons for car ownership and use

The car usage in the UK is multi-dimensional and interrelationships of various factors. The car mode share in the UK is high compared to other European countries although the car ownership is less for UK as the travel by public transport, foot and cycle is not effective compared to other countries (CfIT, 2005).



Source: CfIT, 2007

Figure 1. Car Ownership per 1000 inhabitants in 2004 in Countries

The spatial restructuring of business and employment places and living areas is major factor responsible for increased mobility needs in cities. The growth in car ownership means increased number of trips by individuals and households as compared to public transport (Bagley and Mokhtarian, 2002). The accessibility within activity areas has negative impact on the car ownership in the UK. The increased accessibility among locations tends to increase the use of a particular mode to access urban facilities. The distant locations of shops, recreational facility within neighbourhood have resulted in less walking trips by households in the Britain (RCA, 2009). However, the accessibility by cars has increased the automobile use with few exceptions of negative externalities of road congestion, high parking charges and fuel prices. The household size has positive relation to car ownership in the Britain (RCA, 2009). Results of research studies conclude that desire for increased car ownership is greater among large households with increased average travel distances in the UK. The car ownership also vary among different age groups and old age group have low car ownership and there travelling is usually for shorter distances mostly to specific locations such as health facilities, shopping areas and religious places (Acker, 2010).

In UK, the average share of household expenditure on transport has increased from 13 percent to 17 percent from 1968 to 1998 due to increased car ownership and travel preferences by using private cars (Aldous, 2000). The impacts of growth in travel are significantly associated with economic organisation and personal life styles resulting in an increased average length of journeys and additional monetary costs. There has been a steady increase in the fare levels by government to travel by train or bus in the UK (DfT, 2005a). However, the cost for car ownership has remained constant over last 20 years. It is believed that major factor to restrict some degree of car use in the UK is the fuel price and parking costs. The fuel cost has also been more fluctuated due to international prices and government policy towards fuel duty. However, overall rate of increase in fuel prices remained below the fare increase for rails and buses. These variations in cost have enabled household's decisions for a modal shift preferring individual private cars for major journeys within cities (Headicar, 2009).

4.3 Transport policies and car dependency in UK

There is strong campaign going on both at public and government level in the European cities including UK for a modal shift from private cars to public transport (CfIT, 2005). The transport policy objectives in most cities aim to reduce congestion through alternate transport options in the large urban areas and business centres. The car use in many countries including UK has been encouraged by road investment schemes aiming at reducing journey times. The problems of induced traffic by expanding road capacities have negative impact on fuel use and emissions in the UK. The construction of new roads attracted extra traffic rather reducing traffic congestions in the large urban areas of UK (Goodwin, 1994; SACTRA, 1994; Goodwin,

1997; Hansen and Huang, 1997 & Kenworthy, 1999).

Before and just after Second World War, mobility in British cities was managed through rail transport, buses and walking with few exception of private car use. The shift for goods and passengers from rail transport to road transport started in the 1940. Within no time, automobiles became popular within British society (Headicar, 2009). The proportion of motor vehicles increased by four times in 1963 as compared to 1939 (Savage, 1996). There was no serious policy thinking at government level to device strategies for the growing automobile use in cities. Moreover, the growth of road traffic was under estimated by the Ministry of Transport in the 1950s and later decades of 1960s and 70s (Glaister et al, 2006). The inadequate policy response of the government towards road transport, low spending and priority for the transport infrastructure resulted in severe traffic congestion and safety problems on roads. In UK, an increase in motorised traffic by 7 percent in the year 1989 paved the way for public criticism on transport policies favouring road building activities at the expense of environment damages and reduced public spaces within local communities (Headicar, 2009). With the publication of the White Paper, Roads for Prosperity (DoT, 1989) the environmental implications of the transport got significant importance in the transport policy development. In early 1990s, the focus on the greener image of cities was prioritised to secure British commitments within the European Parliament. Responding to it, Department of the Environment published "This Common Inheritance" (DoE, 1990), followed by the 1991 report by the Department of Transport titled Transport and the Environment which emphasised the need to preserve the environment against automobile use. The immediate actions were taken by 10 percent increase in the fuel duty to minimise car usage and emissions (Headicar, 2009). Analysing the impacts of the traffic on the communities, the idea of building roads was replaced with considering physical management measures for traffic congestion and emissions.

The integrated transport policy was reflected in the White Paper, "A New Deal for Transport" (DETR, 1998a). The policy objective were aimed to consider new approach to minimise the impact of pollution and enable UK command towards climate change initiatives by adopting sustainable transport options for cities. The focus was transferred in developing coordinated approach to public transport, walking and cycling with effective transport land use integration. The white paper was followed by a succession of seven more supported documents on different aspects of transport. Later, the 10 Year Plan was indication by the government towards anti-car transport policies and strategies aiming at the objectives of environment sustainability. In July, 2004 a further White Paper, "The Future of Transport" was published giving formal expression to pragmatic policies which was run by the Conservative governments in the 1980s and 90s (Glaister et al, 2006). Most recently, the UK transport policy aims to reduce the traffic volumes in the large towns by envisaging the implementation of integrated transport system; imposing road pricing and parking fees, strengthening local bus services and introduction of new rail system in medium and metropolitan areas at local levels (Headicar, 2009).

5 INTERNATIONAL EXPERIENCES TO MANAGE CAR DEPENDENCY

High growth in travel demand resulting increased mode share of cars have been progressively addressed in world cities of Barcelona, London, Odense, Singapore, Freiburg, Bogota, Copenhagen, Perth, Melbourne and Tokyo by combining transport and land use policies. The measures adopted in these cities have targeted the car use reduction by limiting and balancing travel demands with improved public transport service and encouraging alternate modes. The most

recognised strategies adopted in these cities are restricting urban sprawl, encouraging mix type developments, increasing public transport patronage through transit oriented developments and reducing travel demands by promoting walking and cycling.

5.1 Singapore

Improved supply of public transport has become a major policy objective in the Asian cities including Singapore (Bresson et al., 2003; Walle and Steenberghen, 2006). Singapore city is a good example, where land use and transport policy have been successful integrated to limit rapid motorisation. City has a high population growth, rapid motorisation and high population densities. There has been huge investment in transport infrastructure over the years improving the mobility to compete with the objectives of economic development in the region. Another distinctive feature of the city is huge income disparities where rich are accumulating the wealth with rising car ownerships and travel. Private cars have major share in daily trips as car trips increased by 23 percent from 1997 to 2004 (Han, 2010). The average kilometres travelled by a single car in 2007 was 20, 800 kilometres annually (Han, 2010; LTA, 2008).

Managed growth of car ownership is interesting feature of the Singapore transport policy lesson over the years. The strong argument behind policy to control motorisation was to protect the scare city land and ensure increased efficiency in the movement of people and goods. The impact of the policy can be as from 1980 to 1996 the car ownership increased from 67 to 100 cars/ 1000 persons and it is forecasted to be increased to 143 cars/ 1000 persons by 2010 (LTA, 2007 & Han, 2010). The measures adopted to restrict motor growth in the city include high import taxes, high registration fees and road taxes initially (Chin and Smith, 1997) and vehicle quota system (VQS), road pricing schemes afterwards. The VQS limits the annual vehicle growth rate and manage vehicle allocations by reviewing current traffic conditions and available road capacities (Koh and Lee, 1994). The measure has been successful to control over the vehicle growth population and 3 percent reduction in growth rate of vehicle was achieved during 1990,s (Sharp, 2005).

The concept of road pricing was introduced in 1975 by implementing Area Licensing Scheme (ALS) in Singapore. The ALS was an attempt to solve the congestion problem in the central area and was applied in CBD and nearby commercial and retail corridors within a specified area (Foo, 1997). These areas were highly concentrated for jobs, commercial activities and tourism therefore, each vehicle except ambulances, police, fire vehicle and public transport (buses) was charged on entering the zone. Later on, in 1998 electronic road pricing was introduced which increased the operational efficiency of the measure substantially and impacts were reduced traffic volumes by more than 20 percent with increased average speed in the city centre (Foo, 2000). The focus of the measure was to control car use rather than direct intervention in restricting car ownership.

The policies of promoting public transport system in the city was targeted with providing a quality based alternate to car use in the city. The attractiveness of public transport system was imperative to the success of vehicle quota system and road pricing policies. The impact of public transport has been delivered by increasing the coverage and capacity of the MRT and LRT system simultaneously. The MRT system is supported with Light Rapid Transit (LRT) in the form of buses and taxies to form the feeder network in the city. The high densities in the central areas of the city provided an opportunity for increased frequencies of the transit system with handsome investment gains for the operators. The system was integrated to provide convenience and comfort in its usage and guiding standards were developed for route designing, scheduling and safety of public transit system.

Table 1 Summary of Policy Measures & Effectiveness in Singapore

Policy Objectives	Strategy/ Measures	Targets/ Results
Reducing car use in city	*Restricting car ownership* • High import taxes • High registration fees • High road taxes	• 143 cars/1000 inhabitants by the end of year 2010 • Decrease in car population by 21% from 1996 to 2006
	Vehicle quota System	• Reduction in automobile growth by 1.5% from 2009 to 2012
	Reduced investments in road expansion projects	• Reduction in road expansion from 1% to 0.5% per annum from 2009
	Road pricing • Implementation of area licensing scheme • Electronic road pricing	• Traffic volume reduced by 20% in road pricing areas • Increase in average speed from 35km/h to 45km/h
Promoting public transport system	*Developing multi-modal transport system (MRT, LRT, buses and Taxis)* • Increased coverage and capacities • Increased frequencies during peak hours • Standardising public transport infrastructure • Improving safety • Integrated and affordable fare prices	• Expanding system capacity by 36% in the year 2020 • Taxis share 11% of daily trips due to low average travel cost • A commuting trips average costs 2% of average household's income
	Improved efficiency of public transport services • Dedicated bus lanes • Bus priority signals • Time tables and scheduling • Traffic intelligence system	

Policy Objectives	Strategy/ Measures	Targets/ Results
Reducing travel demand	*Transport land use integration* • Maintaining compact city form • Development of pedestrian zones in CBD • Hub and spoke structures (Town centre linked by MRT while LRT and buses connecting housing areas with MRT stations • Encouraging walking and cycling within neighbourhoods by mix use developments	

The management measures like bus priority at signals and intelligence system were introduced to increase the operational efficiency of the public transport network. The travelling cost by public transport was controlled by marginal increase in fares to attract more people for public transport usage. It is proposed to expand the system capacity by 36 percent by the year 2020 with increased lines and buses (Han, 2010).

The Singapore experience is unique in the way that two different scenarios of public transport system and car dependent system have been organised. The objective of balancing the motorisation with a public transport system has been the real policy challenge achieved by a range of well-coordinated strategies to control rising car population and usage with increase patronage of high quality public transport facilities.

5.2 Freiburg

The case of German cities is unique where levels of car ownership and use is managed by providing good quality public transport service with increased share of walking and cycling. The policies developed in Germany provide a balance between use of car against other transport modes especially in those areas where impacts and consequences of car dependency were becoming problematic (Wolf, 1986, Schmucki, 2001). The Germany has always high car ownership in Europe after Luxemburg with 546 cars/ 1000 inhabitants against 466 cars/ 1000 inhabitant in Europe (OECD, 2003-2007 & EUROSTAT, 2005-2007).

Freiburg is the most sustainable and environment friendly city of the world. City has a population of about 2, 20,000 inhabitants (City of Freiburg, 2009a). The car ownership rate in Freiburg from 1950 to 1970 was higher than overall car ownership in West Germany. However, with the implementation of car reducing policies in 1970,s the rate started to decline with 419 cars/ 1000 inhabitants in 2006 (Buehler and Pucher, 2009). Freiburg city transport system is far more sustainable than country despite increase in per capita income of the residents. The vehicle km per capita of car use has been decreased by 7 percent on all roads and 13 percent on residential roads from 1990 to 2006 (Buehler and Pucher, 2009). Carbon emissions decreased by 13 percent from 1992 to 2005 and decline in the accident rate have been noticed in last few years (City of Freiburg, 2007a). The financial viability of the public transport is also very high with only 10 percent subsides compared to 28 percent subsidy for public transport in Germany (Buehler and Pucher, 2009).

Table 2 Summary of Policy Measures & Effectiveness in Freiburg

Policy Objectives	Strategy/ Measures	Results/ Targets
Sustainable and environment friendly city	*Reducing car ownership and use* • Discouraging on-street parking • Restricting car use in designated city areas • High road taxes • Improved road safety • Priority to pedestrian traffic	• Decline in car ownership from 422 to 419 cars/1000 inhabitants (1990 to 2006) compared to 546 cars/ 1000 inhabitants in Germany • Decrease in vehicle km per capita of car use by 7% on all roads and 13% on residential roads (1990 to 2006) • Road accidents rate in city is half to overall rate of Germany/ 100000 inhabitant
	Control over carbon emissions • Promotion of green modes over automobiles	• CO_2 emission from transport sector reduced by 13.4% (1992 to 2005)
	Traffic calming • Speed limits within neighbourhoods • Home zoning	• Reduce speed of 30km/h on residential streets and maximum 7km/h within home zone
Reducing travel demands in a city	*Integrating land use and transport policies* • New development along corridors served by LRT system • Car free developments • High population densities in central areas by discouraging sub-urban development	
Encouraging mode shift policy	*Integrated multi-modal public transport system* • Integrated timings and frequencies for peak and off peak hours • Unified ticketing system • Green priority lines at junctions • Reduced cost and travel time by public transport over cars	• Car share trips fell from 38% to 32% (1995 to 2006) • Public transport patronage rose from 11% to 18% (1995 to 2006) • Use of regional passenger card increased to 85% from 37% (1974 to 2007)

	Promoting cycling and walking • Adequate provisions for infrastructure • Pedestrian areas with limited car entrances • Construction of parking spaces away from city centre and major roads forcing people to walk • Behavioural change in daily travel patterns of inhabitants to travel by foot and cycle	• Bike share of total trips nearly doubled from 15% to 27% (1995 to 2006)

The success of Freiburg is attributed to massive behavioural change in daily travels of the people where use of cars has been reduced with shift towards cycling and public transport. There has been strong public and political support enabling the implementation of the anti-car using policies since 1970s (Santos, 2010). The land use and transport policy shift in 1970s emphasised to modernise the tramway, to promote the integrated bikeways and converting historic city centre into pedestrian zones with limited car entrance (Newman and Kenworthy, 1999). Later in 1979, the transport plan officially included the promotion of green modes alternate to private automobiles. The land use policies guided the new developments along public transport corridors particularly by expanding light rail transit. The last land use plan prepared for the city focus on the development of car free neighbourhoods and high density developments along light rail routes to strengthen the neighbourhood identity by reducing the travel distance among various land uses. The central developments have been prioritised over suburban development to increase residential densities. The transport measures include traffic calming of residential streets with a speed of 7km/ hour to 30 km/ hour with priority for pedestrian and cyclist over cars. The city parking spaces have also been reduced to discourage use of cars (Buehler and Pucher, 2009).

The dignity of Freiburg is its integrated public transport network and light rail transit covering 36.4 kilometres in 2008. The light rail is expanded in radial pattern to provide maximum residents access to their work places within a distance of 300 metre. The share of light rail in public transport service is 70 percent with 30 percent public transport served by buses (City of Freiburg, 2009a). The frequencies and timings of public transport networks are well integrated to accommodate peak and off peak passenger movements. The public transport networks have been provided with green priority lines at major locations and junctions. The ticketing system is also unified where one can travel on different transport modes using a single ticket and there are special incentives for regional ticket and discounts for student travelling. The operation of public transport ensures complete advantages in terms of time and cost over cars which have been key success of the city.

The walking and biking facilities have been encouraged for shorter trips by introducing traffic calming measures. To restrict car use the parking areas and garages for motor cars have been intentionally built far away from the activity areas forcing people to walk or use public transport to reach their destinations. The residential parking is only reserved for the residents and special permission are required for on-street parking by the visits in those neighbourhoods. The parking cost is very high in central areas and comparatively less moving on the outskirts. The consistency in policy development and implementation supported with

strong behavioural change has changed the fortune of the city making it more attractive and environment friendly.

5.3 Copenhagen

Copenhagen is one of the largest metropolitan cities in North Europe and capital of Denmark. The population of the metropolitan city stands around 1.8 million in 2008 (Santos, 2010). The urban growth pattern of the city is famous by post-war "Finger Plan" where urban development and growth of the city takes place along five railway lines to north, west and south directions.

The car ownership in Greater Copenhagen was 333 cars/ 1000 inhabitants in 2006 (CfIT, 2007). The overall development in car traffic shows an increase of about 20 percent from 1990 to 2008. The increase has been noticed on the primary distributors; while there have been no major changes to secondary distributor and district streets (Niels, 2009). The number of private passenger cars was 21 percent higher in 2007 than in 1999. From 2006 to 2007 there was an increase of slightly over 4 percent in the number of private cars in city. From 2007 to 2008, the volume of traffic on the road network as a whole has remained virtually unchanged (http://www.progress-project.org).

The increased car use started to threaten the city in 1980s. To address the issue, city authorities implemented a policy to move traffic from housing areas to main roads supported with traffic control measures by reducing signals green time in the central areas to discourage motor trips. Another important measure was effective distribution of travel demands over transport modes shifting large number of commuters from cars to bicycles and public transport modes. It was aimed in the transport policy to limit the inbound traffic in the congested areas and managing transport demand in these areas through public transport and cycling facilities, although policy remained under pressure due to growing car ownerships and use by the higher income groups.

The focus of transport policy for last few years is the development and expansion of public transport system in the city. The multi-modal public transport network of local trains, metro lines, buses, and express buses serve the city and regional areas to reduce congestion on limited road capacities central areas of the city. The barriers to road expansion in the old city, the most viable solutions to manage car usage have been alternate transport modes, increased traffic controls and management and improved public transport coverage and service quality (http://www.progress-project.org). Public transport is accessible from about 1,200 bus stops and 40 stations to trains, metropolitan S-trains and the Metro. More than half of passengers travel by buses, while the rest use the train or Metro. The number of Metro passengers has risen by 15 percent from 2007 to 2008 (Niels, 2009).

Copenhagen is a pioneer of introducing competitive tendering for private bus operators in city. Due to falling ridership and increasing subsidies during the 1980s, in 1990 in city, the bus service operation was privatised by introducing competitive tendering system providing number of incentives for operators on improved service quality. These management reforms were successful to reduce operating costs per bus hour by 24 percent over ten years, and stress on service quality in the contract specifications resulted in increase ridership (Niels, 2009). In late1990s, Copenhagen car use has been discouraged by eliminating the parking space every year replacing with green areas and public spaces (Newman & Kenworthy, 1996).The increase in car ownership has put great pressure on street parking. Partly for this reason, the city adopted a parking strategy in 2005, one result being the opening in 2008 of a municipal parking facility for the public and the start of building work on three fully automated underground parking installations due to high concentration of automobiles in specific areas of municipality. Road pricing is another measures adopted to reduce the flows of cars in the city.

Table 3 Summary of Policy Measures and Effectiveness in Copenhagen

Policy Objectives	Strategy/ Measures	Targets/ Results
Improving air quality	*Reducing car ownership* *Control over carbon emissions* *Reducing car use* • Reduced green times for automobiles in city centre • Road pricing	• Control over car ownership with 4% increase in car traffic in 2007 • Unchanged traffic volume in 2007-08
Integrating transport and land-use policy to reduce reliance on the car	*City growth along main railway lines to restrict urban sprawl* *Limiting inbound traffic in city centre and managing demand through improved land use planning and alternate modes* *Replacing car parking with green spaces in city centre*	
Improving the quality of public transport, to reduce reliance on the car	*Multi-modal public transport system (local trains, metro lines, buses, and express buses)* • Development and expansion of public transport system • Improved service quality of public transport • Increased coverage of the public transport services • Integrated fares • Introduction of competitive tendering for public transport operations	• Metro passengers increased by 15% (2007 to 2008) • Increase in ridership • • Increased growth in public transport passenger in last five years • 24% reduction in operation cost/bus in last ten years
	Encouraging alternate transport modes • Construction of green cycle tracks • Construction of bike lanes • Provision of parking spaces for bicycles • Cycle sharing network • Improve safety for cyclist	• Highest cycling and walking share in Europe • Cycle trips share to work places to be increased by 40% in 2012 • Cycling accounts 26% of total mode share • 50% reduction in road causalities by year 2012

Copenhagen has a unique culture of dominated bicycle share and use. The city cycle and walking mode share is the highest in Europe (Schwanen, 2002) as there is an establish cycle sharing network operated in a city (Santos, 2010). There are nearly 390 bike roads, of which 320 are cycle tracks, 40 green cycle routes and 15 cycle lanes. For year 2025, it is estimated to invest about 123 million of Danish Krone (DKK) to improve the existing bike routes as well to construct new route (Niels, 2009). Although a lot of improvement and investment is still required on improving road safety for bicycles and provide parking spaces for increased use of the bikeways (Santos et al, 2010). In 2002, Copenhagen cycle policy determined certain targets to be achieved in next ten years mainly, increasing the share of bike trips from 34 percent to 40 percent, reduction in bicycle causalities by at least 50 percent and measures to increase the comfort speed by 10 percent (Santos et al, 2006).

5.4 Melbourne

Australian cities are most extensive in their level of car dependency when measured against their transportation patterns, infrastructure and land uses. The analysis by Newman and Kenworthy (1999) concludes that Australian cities utilise 12-13 percent of their city's wealth on passenger transportation system while in European cities it is estimated about 7-8 percent spending on the transportation. The Australian Bureau of Statistics (ABS) survey results and Census data published in March, 2009 indicates 15.7 million vehicles registered in the country with a growth rate of 13.1 percent in last 5 years with 18.4 percent increase in buses against 13 percent increase in passenger vehicle due to policies aiming at reducing car dependency in Australia. There were 720 passenger vehicles/ 1000 population in 2009 compared to 674 vehicles / 1000 resident population in 2004 with 14,600 kilometres travelled by each vehicle (http://www.ausstats.abs.gov.au).

Car is the dominant mode of transport in Melbourne with 91 percent share of car trips in 2008 (DTV, 2009). The city has an extensive public transport system of trams, buses, coaches and trains. The city tram system is one of the largest in world with 245 kilometres of double tracks providing access to inner urban and sub-urban areas of city. The city has an integrated public transport network served by 15 lines and more than 200 stations (VTPI, 2010). The public transport share in overall trips is only 9 percent despite government efforts to increase public transport patronage to meet future transport challenges (Loader and Stanley, 2009). The suburban rail network and tram network having more than 25 routes providing service for inner- and middle-suburban areas; and bus services throughout the metropolitan area connecting train lines and major centres (DTV, 2009). The investment and recent improvement in public transport system has remarkable impacts in increasing bus patronage which has been grown at a rate of around 4.6 percent in 2007. The growth in bus patronage is characterised by upgraded service levels and extension of existing bus routes (Loader and Stanley, 2009). Due to heavy traffic volumes, the city roads are congested and mostly operated on their full capacity (http://www.melbtrip.com/).

A gradual increase in cycle trips has been noticed in Melbourne within few years mainly due to population growth and job increase within the core city. There has been an increase bicycle trips by 78 percent within the central business district of city (Pucher et al, 2010). The other factors contributing to increases in cycling are improvements in inner Melbourne cycling infrastructure, existing grid iron street pattern providing maximum connectivity within neighbourhoods (Pucher et al; Davison, 2004), mixed uses within core city and government policy responses discouraging car travel. The cycling culture is developing slowly and requires immediate government attention particularly linking cycle routes with existing public transport network.

The impact of traffic calming is limited within core city areas. The application standards and nature of traffic calming measures in Melbourne is far less than European cities of Germany, Denmark and Netherlands. The speed limit on local roads is 50 km/h while school zones and neighbourhood streets with heavy pedestrian volumes allow speed limit of 40 km/h. (Pucher et al, 2010; Garrard, 2008). Few streets share speed limit of 10km/h; although motorists regularly violate posted speed limits on streets (Australian Associated Motor Insurers, 2009).

To manage car dependency in the city, a comprehensive program has been covered under Victorian Greenhouse Strategy and Melbourne 2030 plan. The 2030 plan for Melbourne introduces key actions to improve the efficiency and delivery of city transportation system aiming at reducing car dependency in Melbourne.

a. *Upgrade and develop the principal public transport network and improve local public transport services*
b. *Encourage sustainable travel in city*
c. *Provide for the transport needs of growth areas*
d. *Ensure integrated planning for metropolitan transport*

(www.dse.vic.gov.au/melbourne2030)

5.5 Barcelona

Barcelona is a cosmopolitan Mediterranean city of Spain which presents combination of historic Roman patterns in its urban street along with modern urban design elements of 20th century. In last three decades, city carries the image of highly potential investment area and is a key business centres supported by its strategic transport links, attractive environment and good quality of life. The expansion and improved coverage by transport network has resulted in the decentralisation of the population, high car ownership and use giving rise to motorised traffic threatening the city environment. The car ownership in year 2000 was 424 cars/1000 inhabitants in the city (CfIT, 2007). The policy shift towards encouraging public transport in the city got popularity in the 1990s to reduce car dependency on expanding areas of the city. The public transport system offers variety of transport modes providing coverage up to 30 kilometres outside the city and regulated with integrated fare system of multi-use ticketing. The public transport service consists of rail transport, metro lines, regional rail transport, bus lines and tram lines (http://spicycles.velo.info).

To manage growing motorisation in city, land use transport integration has played a vital role in guiding the new development within the existing high density areas and locations served by rail. The Metropolitan Transport Authority is responsible to set transport policy objectives in the city. The Authority has aimed to increase the share of public transport, and reduce the car use by setting targets to extend rail network to densely populated areas with a maximum distance of 500m from a metro station and 800m from local train station. The transport policy have planned to balance the supply and demand for public transport with targeted passenger for buses, trams and rail service in higher demand areas.

The current fare structure has enabled to reduce journey prices in the city. The integrated ticketing system has been successful in increasing the multi-modal transport journey from 8 percent to 21 percent in 2003. To discourage use of cars the city council has imposed strict parking controls by reducing on-street provisions for commuters and visitors which helped to reduce congestion in the city centre. Another important aspect of parking policy is the shifting of the on-street parking to underground parking garages. Car parking spaces within city centre have been reallocated for pedestrian mobility. The policy of access control has reduced, private transport (cars and motorcycles) trips by 8% in the inner city, and 4% in the suburbs since 1999 (Dunning, 2005). The central areas of the city have been converted into pedestrian areas to restrict car use and

encourage walking trips. However, the transport governance gaps and political conflicts are the major challenges to transport policy development and delivery for the city. The coordination and integration among regional government, Metropolitan Transport Authority and individual municipalities is key determinant towards successful operations of the public transport service and other policy measures (Dunning, 2005).

6 DISCUSSION AND FINDINGS

The trends in car ownership and use in world cities identify common challenges of people moving to the suburbs, more reliance on cars, and increased travel (vehicle kilometres) and long travel distances in urban areas. The variation in the spatial and temporal growth patterns of cities have impacted on the development structures and land use densities, provision and quality of transport infrastructure, planning frameworks and travel behaviours. The response of cities to solve the problem of growing traffic and car use has been combination of measures guided by transport policy objectives and environment safeguards. Nevertheless, success of these policy and fiscal measures has been attributed to level of integration, encouraging alternative modes, land use controls, and public participation.

Table 4 Comparative Review of Transport Policy Measures in World Cities

Measures	Cities				
	Singapore	**Freiburg**	**Copenhagen**	**Melbourne**	**Barcelona**
Multi-modal public transport system to improve quality, reliability and patronage	√	√	√	√	√
Restricting urban sprawl through compact city developments for higher population densities	√	√	**X**	**X**	√
Road pricing policies to reduce congestion and car use	√	**X**	√	√	√
Integrated fares and ticketing system	√	√	√	√	√
Parking standard (reducing parking spaces and charging vehicles	√	√	√	√	√
Pedestrian zone	√	√	√	√	√
Traffic calming and home zoning		√	√	√	√
Encouraging alternate transport modes (walking and cycling)	√	√	√	√	√

Measures	Cities				
	Singapore	**Freiburg**	**Copenhagen**	**Melbourne**	**Barcelona**
Land use and transport integration to reduce travel demands	√	√	√	√	√
Transport demand management	√	√	√	√	√

The delivery of policy measures to reduce car dependency in these cities has been combined with availability of high levels of funding for large-scale public transport investment programmes, infrastructure development for cycling and pedestrians and strong institutional support. Regulating land use locations, types, sizes and population density in development process have been successful to reduce the travel demands in cities, particularly by car. However, the effectiveness of land use strategies is connected with people's decisions about their living and proximity to workplaces. The increased infrastructure capacity, speed limits in city areas, high parking charges and improved car technologies cannot guarantee an immediate reduction in car use rather assessment of travel patterns describing when and where people drive, particularly the home and work trips and during the peak hours would guide to choose traffic demand management options to limit car use in a city. The shift from private cars to public transport is not possible at once rather policy makers need to design policies discouraging the car use and providing choices in public transport travel. The attractiveness to public transport service has been achieved by integrating various public transport modes (buses, rails and trams) in many cities.

The UK case is different from other European countries presenting high level of car reliance with 85 percent mode share by car but a very low use of public transport (CfIT, 2007).

Although in last few years, increase in rail travel across the UK has resulted in some improvements in the public transport share. If we compare the world cities in Europe, only London in the UK possesses high share of public transport use. The cities of Manchester, Glasgow, and Birmingham remain higher in car use compared with Lyon, Copenhagen, Munich and Vienna. In UK, the cost of travelling by public transport is quite high compared with other European countries because the major portion of public transport operating costs are recovered from users through fares (Garling et al, 2002). The cost of travelling by car in UK is cheaper as compared to other European countries although the fuel pricing is also on the higher side (CfIT, 2005). The parking cost in case of London and other metropolitan cities of the UK is also on higher side but the combined cost for using cars against the public transport is much lower than countries like Germany, France, Italy, Denmark, Austria (CfIT, 2007). In UK, huge investments in transport sector has been made over a period of 50 years but there exist no official process to monitor the impact of these investment in the form of saving in travel time, travel distance and travel costs. (Headicar, 2009). Moreover, the weak policy response in developing cycling and walking programs combined with behavioural constraints has been major obstacle to shift car use in the UK.

The UK commitment on Voluntary Agreements of CO_2 emissions has potential to justify government efforts in reducing car dependency

in cities. The country needs a strict fuel consumption targets during policy development for national, regional and local areas. The emissions standards for car use need to be legislated with respect to on road distance travelled and carbon emissions in line with the directions of the EU Commission and OECD agreements. The impact of these policies in the long run could result in reduced car travel and kilometres travelled in cities (Bonilla & Foxon, 2009).

The effectiveness and success of various policy interventions to reduce car dependency in international cities has been approached with strong institutional support involving the public to frame major policy decisions in solving traffic problems (Garling et al, 2002). The key success instrument of public participation is lacking in the UK (Jakobosson et al, 2000). Moreover, the behaviour trends of car use including the pull measures and push measures to discourage and encourage car use are important consideration for designing policies in managing car dependency. The travel choices of the people changes over time, therefore targeting the behaviours of car use require integration and impact analysis of other transport modes guiding combined policies to manage car dependency in UK. The significance of non-motorised transportation for a city is advantageous in economic and environment grounds as walking and cycling cost is zero compared to motorised modes and involves almost negligible environmental costs. UK cities need to re-frame the policy programs by providing maximum coverage and promotion for non-motorised transport modes with increased capital investments. .

7 CONCLUSION

Car dependence grows continuously over time consequence to government failure in adequate supply provisions for public transport services. The land use changes in a city tend to relocate the services away from residential areas shifting people's lifestyle with increased reliance on cars due to its immediate availability for journeys. The lessons from international cities conclude that nature of car dependence in urban areas of the UK have high potential to substitute large portion of daily trips by other transport modes. The comparative review of car dependency experiences in various international cities identifies a strong relationship between development patterns and car use. The form of the future development in UK cities needs to be structured encouraging transit oriented and non-motorised modes over automobiles. The type of relationship between cost of cars (both fixed and variable costs per kilometre) and car use share are important factors to be considered in the policy development of reducing automobile dependence. Promoting sustainable transport options in implementing city plans can bring immediate and long term benefits to reduce the impacts of car dependency in the country. The implementation of transport strategies (traffic calming, pedestrian area schemes, dedicated bicycle lanes, improved storage, park and ride, transport demand management measures and improving safety for pedestrians and cyclist) need priority to achieve transport sustainability in cities. The implications of growing demand for car travel are significant for economists and policy makers in the UK. The physical planning strategies to manage car dependency in cities needs to be coordinated with the economic policies addressing the car ownership use and car cost factors with heavy charges. An informed analysis of present demand and future forecast of motor vehicle growth is essential for integrated planning, designing and road infrastructure developments, traffic management, allocation of resources, emissions and fuel demands. The application of congestion charges, bus priority lanes, cycle tracks and pedestrian zoning measures require local level ownership during policy formulation and implementation phases to enable mode shift and increased public transport patronage, currently lacking in the transport land use policy development in the UK. Managing car dependency will itself reduce the CO_2 emissions

in the transport sector. All is required an holistic approach for implementation of sustainable transport policies, standardising economic instruments, applying technological innovations, investing in public transport, walking and cycling, changing people's behaviours and introducing physical measures without challenging the mobility within a city.

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EXPLORING LAND USE-TRANSPORT INTERACTIONS IN THE GREATER DUBLIN REGION USING THE MOLAND MODEL

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ABSTRACT

Urban regions are increasingly important given the rapid pace of change of land use in these regions driven to some extent by changes in demography, economic development, environment, transport and technology. The MOLAND model provides a spatial illustration of alternative development patterns and trends; it offers a basis for the analysis of the spatial implications of particular policies and provides a useful platform for discussion and comparison of land use – transport interactions under different scenarios. The MOLAND transport model was used for the Greater Dublin Region, running two possible scenarios of transport infrastructure development in the region. The influence of the Metro North line was analysed to show its effect on transport flows in the region. The results of comparison analysis are discussed in terms of the implications on future settlement and transport flow patterns in the Greater Dublin Region as a whole and particularly in the areas intersected by Metro North.

Keywords: MOLAND, model, transport, land-use, cellular automata, scenario, Metro North

1 INTRODUCTION

Urban regions are increasingly important given the rapid pace of change of land use in these regions driven to some extent by changes in demography, economic development, environment, transport and technology. For example, between 1996 and 2006 Ireland's population grew by 17% from 3.6 million approx. to 4.24 million approx. The numbers at work increased by 40%, the number of private cars per 1,000 adults increased by 38% and the total number of licensed vehicles increased by 72%. Energy consumed by the transport sector increased by 100% and emissions of greenhouse gases from transport increased by 88% [1-4].

In 'A New Transport Policy for Ireland 2009 – 2020' [4] the Government reaffirms its view that transport and travel trends in Ireland are unsustainable. Despite the Transport 21 initiative to provide 7 light rail and 2 metro infrastructures by 2016 (Figure 1) which has been partially implemented, it is expected that as a result of current policies, congestion and transport emissions are likely to increase and that economic competitiveness and quality of life may decline.

Given these issues, tools which can integrate transport and land use dimensions to assist in assessing policy options have great potential. The MOLAND dynamic land use model provides a spatial illustration of alternative development patterns and trends; it offers a basis for the analysis of the spatial implications of particular policies and the interactions of multiple planning actions.

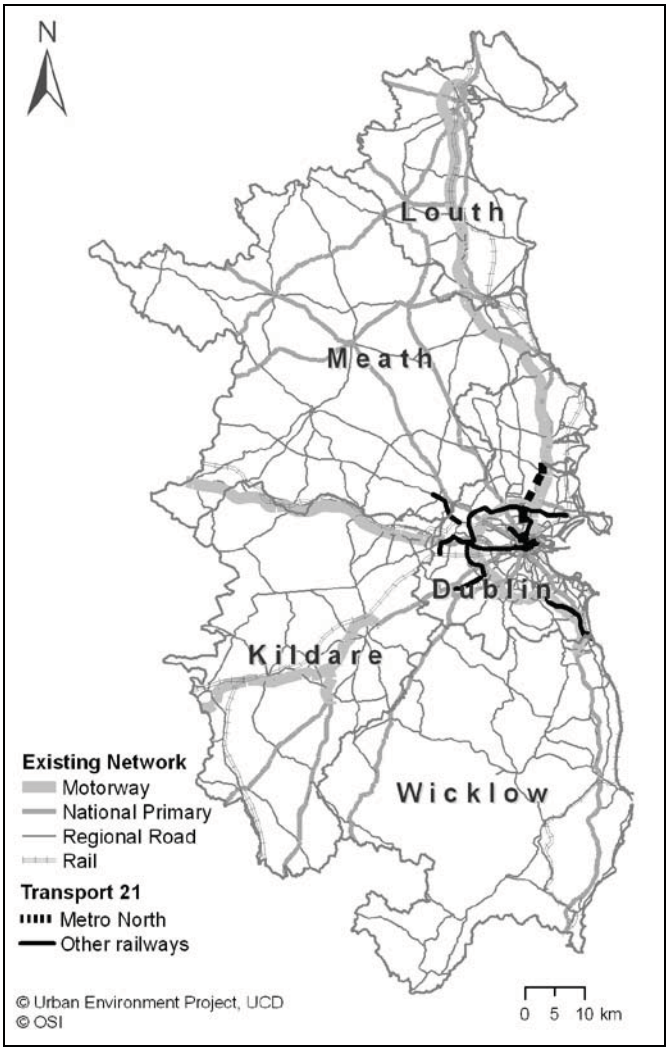

Figure 1. Existing and planned transport network in the Greater Dublin Region

Thus, MOLAND provides a useful platform for discussion and comparison of land use – transport interactions under different scenarios which can inform policy interventions.

2 THE MOLAND MODEL

The MOLAND model was developed as part of an initiative of the European Commission's Joint Research Centre as a response to the challenge of providing a means for assessing urban and regional development trends across Europe. In order to capture the processes effecting the spatial configuration of an area, MOLAND represents the processes operating at three geographical levels: the Global (the whole area), the Regional (sub-regions/counties) and the Local (cellular units) [5]. The combined Global and Regional levels constitute the so-called macro-level of the model, while the Local level represents the micro-level of the model. At the Global level, the model integrates global/aggregate figures taken from economic and demographic growth scenarios representing development in the study area. From these, growth figures for the population and jobs per economic sector (industry, commerce and services) are derived and entered into the model as trend lines. Then the Global growth figures are imposed as constraints on the Regional level. At the Regional level consisting of 5 counties in the Greater Dublin Region (GDR), a dynamic spatial interaction based model [9] arranges for the allocation of Global growth as well as for the interregional migration of activities and residents based on the relative attractiveness of the counties. Then, at the Local level the detailed allocation of economic activities and people is modelled by means of a Cellular Automata based land use model. Thus, estimates of the population will be provided for within residential and estimates of the economic activities will be provided for within industrial, commercial, and service land use types. The land use type assigned to any given cell is determined by an algorithm which aims to satisfy the demands for land use in each time step [5]. The following main elements of the model determine whether a cell is taken in by a land use or not:

- Suitability: a composite measure determining the physical, ecological and environmental appropriateness of cells to support a land use and the associated economic or residential activity. It is presented by one map per modelled active land use class.
- Zoning: specifies whether a cell may or may not be taken over by a specific land use. It is usually based on statutory zoning designations.

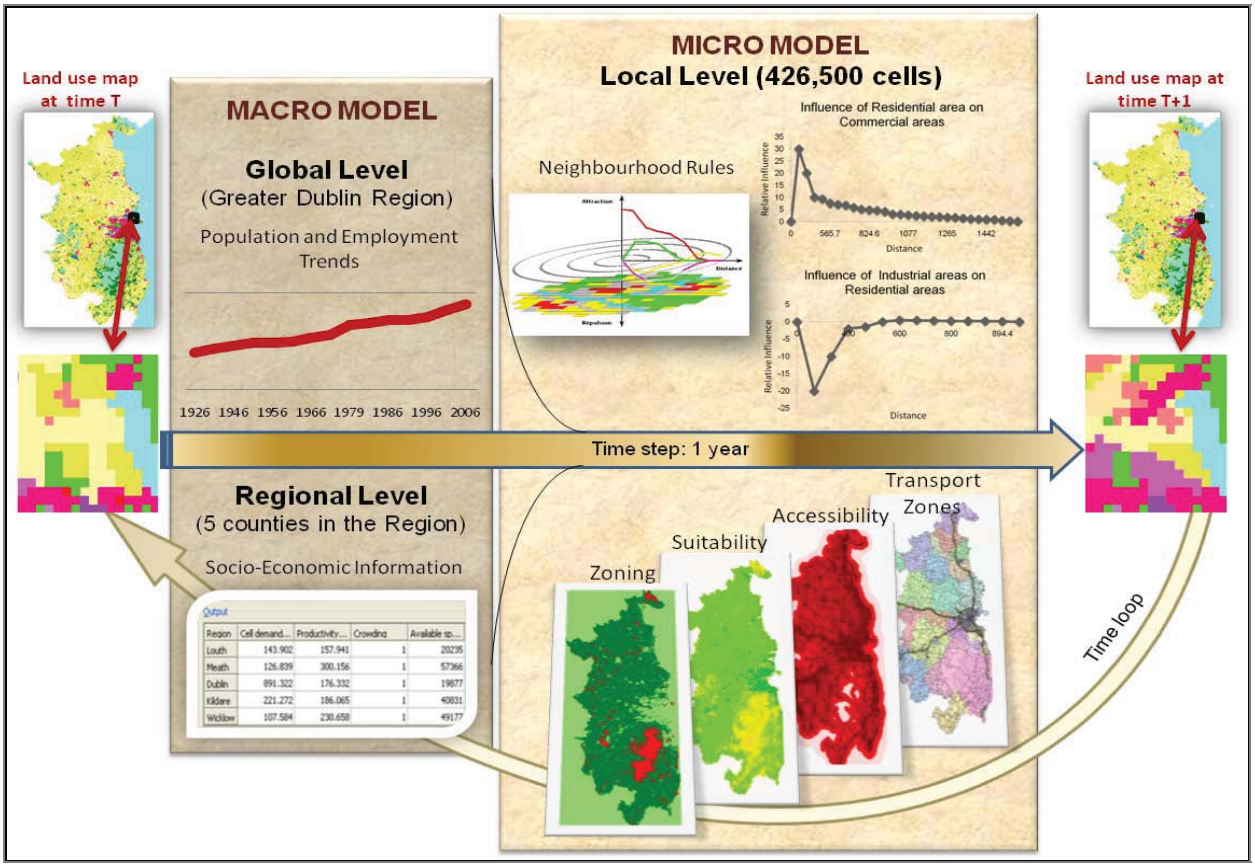

Figure 2: Land use transition in MOLAND.

- Accessibility: describes the accessibility of a cell to the transport network.
- Neighbourhood rules: express the dynamic impact of land uses in the surroundings of a location. For each cell a set of rules determines the degree to which it is attracted to, or repelled by, the other land use cells present in the neighbourhood.

Based on these elements the model calculates the transition potential for each cell for every simulation time step (Figure 2). Cells are changed to the land use for which they have the highest potential until regional demands are met.

2.1 MOLAND Transport model

The MOLAND Transport model is built as an additional element in the MOLAND toolbox. It is based on a classical four step approach [6]. The land use model serves as an input to the transportation model, whilst the transportation model again influences the land use model by means of a local accessibility term. Hence the MOLAND Transport model is a dynamic model. Both transport and land use are calculated for every time step (yearly).

At the regional level, the transport model uses information from the land use model in the form of travel demands. Cells with land uses have a density of population or jobs that is used for calculating travel demand. Besides land uses associated with population and jobs, other land uses are actively used as well. Although they are not expressed in terms of activities and densities they still contribute to the transport model for estimation of transport flow direction. For example, recreational areas generate trips for people visiting them.

The numbers of people and jobs per zone are used to calculate the production and attraction of each transport zone. Trips are then assigned to the transport network based on these travel demands and the costs to move from one zone to another. Costs are an aggregate measure for distance, travel time and other costs to move from one region to another. These costs are incorporated into the regional model as interregional distances and influence the distribution of activities over these regions.

At the local level, the potential for certain land uses is determined by their local accessibility, among others i.e. their distance to the transport network and the influence of this. The influence on the local accessibility is dependent on the volume of traffic on that part of the network.

Purpose and Modes

The model allows for the introduction of trips for different purposes defined by the origin and destination, in this case home-to-work, work-to-home, work-to-work or other. It is assumed that different activities give rise to a number of trips, either as an origin or a destination.

The MOLAND Transport model supports one mode modelled endogenously (in this case mode 'Private' transport) and several modes modelled exogenously (in this case, one general mode 'Public' transport).

Transport Network

The transport network is included as a GIS shape file. The database aligned to this shape file contains several fields, described below:

'Roadtype' is an integer value that identifies the different road types for the transportation model. In the GDR model the following road types were used: Motorway, National, Regional, Other, Railway, Motorway Junctions and Railway Stations.

'AccType' is an integer value that identifies road types for the local accessibility.

'Length" is a double field expressing the length of a single link in meters.

'Speedlimit' is a double field representing the speed limit on a particular link expressed as kilometres per hour.

The total capacity of a link is indicated with 'Capacity', which is expressed as mode equivalent per hour. The mode equivalent is typically the number of cars. Besides the speed limit, the capacity depends on the available number of lanes.

'Extracost' is a field to indicate costs represented in Euros that are intrinsic to travelling on a link, for example toll costs.

The road and rail networks of 1990, 2000 and 2006 years were used in the MOLAND model GDR application. To prevent inconsistencies the 1990 and 2000 datasets were derived from the most up to date 2006 dataset, thus ensuring positional accuracy between the reference years [7].

For accessibility mapping the key data required is the position of motorways and primary and secondary road junctions. To ensure these positions were as accurate as possible the existing dataset was compared with ancillary data provided by the Dublin Transportation Office and any required modifications were applied to the dataset.

Transport Zones

The MOLAND transport model also requires a map indicating the boundaries of the transport zones. The boundaries of the regions (counties) should

also be boundaries of the transport zones; in other words a transport zone must be fully contained in only one county and every cell of each county should be covered by exactly one transport zone. Based on these and other requirements the transport zone map of the GDR was developed using the boundaries of the Urban and Rural Districts defined by the CSO [1]. Initially, thirty-three transport zones were defined for the 5 counties. As a result Dublin city was covered by only one transport zone. However, given the high volume of transport flows in the city region Dublin was further subdivided using Local Electoral Area boundaries. Figure 3 illustrates the resulting 44 zones.

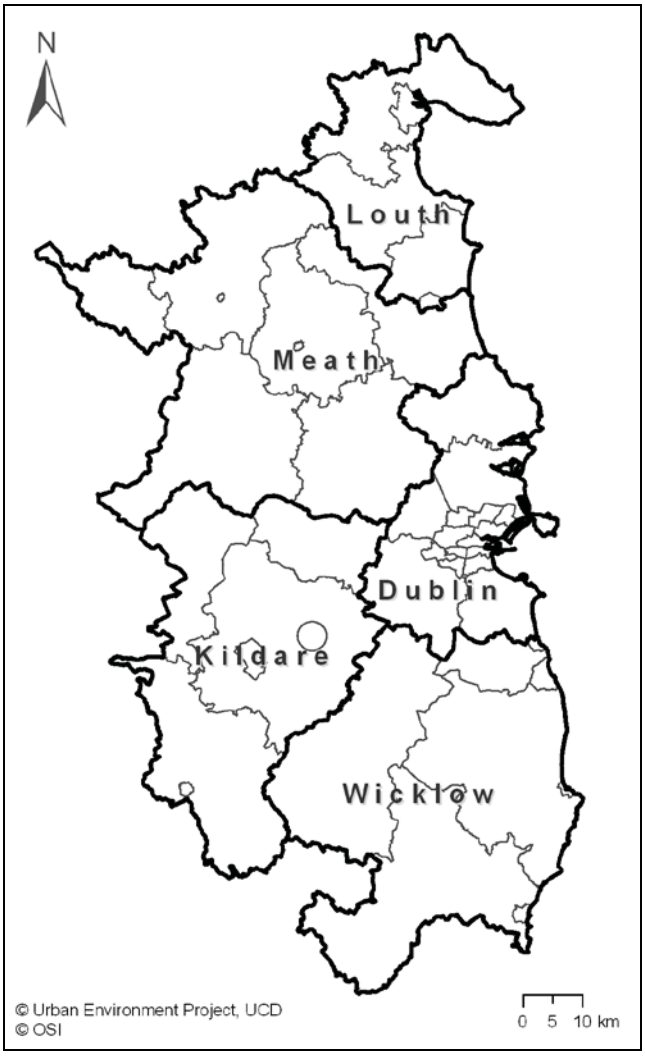

Figure 3. The MOLAND transport zones for GDR

Traffic Flows

In order to populate the various data tables within the transport model, an examination was carried out of the 2006 Place of Work Census of Anonymised Records (POWCAR) data set provided by the CSO [1]. This dataset contains just over 1.8 million records and provides information at an individual, but anonymised level for all persons over the age of 15 years in the State. Information is provided about place of residence, at an Electoral District (ED) level, and place of work, at a 250 sq m level, along with socio-economic information and information about the principal mode of travelling to work, school or college.

Within the remit of the transport model data preparation scheme, a series of matrices were required to describe the number of trips within the study area. These trips flow from one origin to multiple destinations and vice versa. As a result, the information from POWCAR of most use in this work is that pertaining to both place of residence and place of work, at an ED level, and on the means of travel to work.

The initial process involved the development of the 2006 transport flow Origin-Destination matrices. From the point of view of adequate calibration, it was also necessary to develop a series of matrices that describe the 2000 situation. In the absence of firm data for this year, a set of assumptions are made in order to estimate 2000 levels in terms of trip numbers. Details of data preparation and estimation for the transport model are described by Shahumyan et al. in [7].

2.2 The Model Calibration

In the scope of Urban Environment Project the MOLAND model was adjusted and calibrated for the Greater Dublin Region based on 1990, 2000 and 2006 social-demographic, transport and land use datasets [8]. Results of the calibration show that MOLAND performs quite well in terms of regional estimates of population and jobs, which compare favourably with actual estimates and constant share projections. Fuzzy kappa comparisons and cluster size frequency plots of the simulated maps also show that the model simulates realistic images of development trends and the spatial dynamics of the region [8]. The Transport model was calibrated separately by Research Institute for Knowledge Systems (RIKS) based on 2000 and 2006 datasets.

3 SCENARIOS

The MOLAND model was used to simulate and analyse two scenarios of development in the GDR from 2006 to 2026:

- Scenario 1: Business as Usual (BU) - a continuation of the current settlement patterns, without substantial development in transport infrastructure.
- Scenario 2: Metro North (MN) - a continuation of the current settlement patterns, with implementation of the Metro North project of Transport 21 by 2016.

The CSO's regional population projection "M2F1 Traditional" [3] was used for both scenarios. It combines continuing though declining international migration with constant fertility and a return to the traditional pattern of internal migration by 2016. But, the Greater Dublin Area (GDA) used in CSO projections, comprising the Mid-East region and the Dublin region, is of similar, though not identical extent to the MOLAND study area (GDR). The GDA consists of the Dublin, Meath, Kildare and Wicklow counties. The MOLAND study area consists of the Dublin, Meath, Kildare, Wicklow and Louth counties. Therefore, the population for Louth in 2026 was estimated and added to the projected GDA population in 2026 [7].

Place of work datasets for 2002 [2] and 2006 [1] were used to estimate the appropriate job numbers for 2026 [7]. The summary results are presented in the table below.

Table 1. Population and employment data of GDR used in the MOLAND model.

	2006	2026
Population	1,773,803	2,553,149
Industry jobs	259,800	380,573
Commerce jobs	321,790	559,519
Services jobs	211,656	362,129

As the name suggests, Scenario 1 explores a continuation of the current, dispersed settlement patterns. Reflecting the current economic climate delivery of Transport 21 projects is delayed.

Scenario 2 also explores dispersed settlement patterns using the same population and job projections. However, Metro North is in place by 2016. Using underground, surface and elevated tracks, Metro North will operate from St Stephen's Green, via Dublin Airport, to Belinstown, north of Swords (Figure 4). An estimated 35 million passengers a year will travel on this service. The journey time from St Stephen's Green to Dublin Airport will be in the region of 20 minutes [11]. Figure 4 shows Metro North and the transport zones it intersects within Dublin.

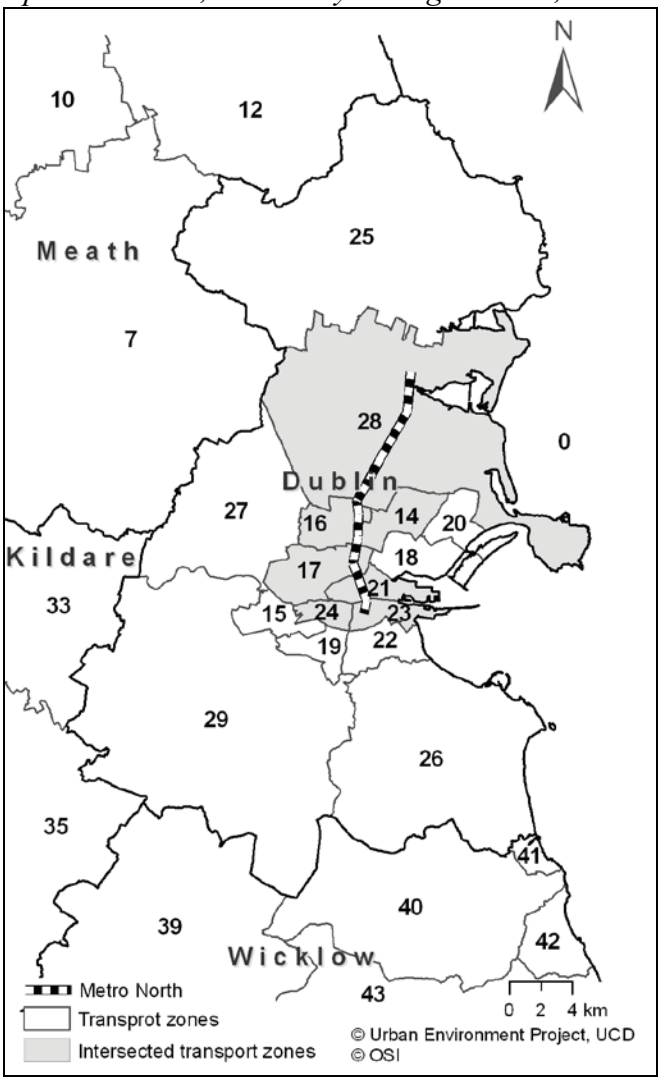

Figure 4. Metro North and the transport zones used in the model

4 RESULTS

The focus of this study was to estimate the influence of the implementation of Metro North project on travel and land use patterns in the area. Therefore the same projections of population and jobs, and the same accessibility parameters were used in both scenarios. The differences in the simulated land use maps presented in Figure 5 are not significant and can be explained by the random factor in the CA algorithm [5].

However there are noticeable differences in the transport indicators calculated by the model.

The total number of trips in the GDR by private transport is about 0.5% more in the case of the BU scenario; whilst for public transport it is 2.1% more in the case of the MN scenario. This is because with the introduction of a quicker and shorter public transport option in the MN scenario, the generalised cost of travel by public transport is reduced resulting in higher usage of public transport.

Average trip distance in the region for both transport modes are about the same for both

scenarios, 9.5 km for private and 10.5 km for public transport.

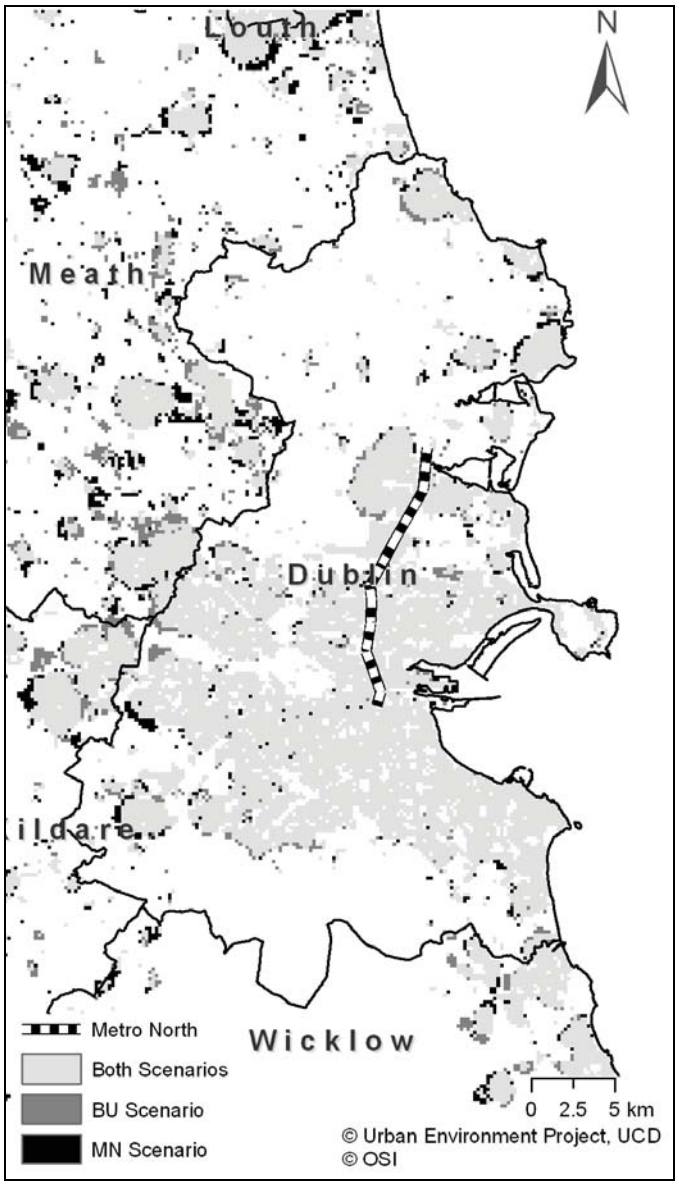

Figure 5. Comparison of urban areas in County Dublin from GDR 2026 maps generated by BU and MN scenarios

Average trip duration in the region by private transport is about 9 minutes in both scenarios. Trip average duration by public transport is about 29 minutes in the case of the BU scenario and 28 minutes in the case of the MN scenario. Though a 1 minute difference does not seem significant, it is noted that it is based on the average trip duration for all 44 transport zones in the region, while Metro North line intersects with only 6 of them (Figure 4). Furthermore, the transport flow between zones was analysed, concentrating on the zones intersected by the Metro North line. As illustrated in Figure 4 the Metro intersects transport zones numbered 14, 16, 17, 21, 23 and 28. The comparison shows that the number of trips between these zones by private transport is about 4% higher in the case of the BU scenario. Whilst in the MN scenario there are 20% more trips between these zones generated by public transport. This shows the immediate impact of the project on specific zones is quite significant.

5 FURTHER RESEARCH

Initial results of the study are interesting and illustrate the potential of MOLAND with a detailed transport model to assess the impacts of a new transport infrastructure on traffic flows However, it has to be noted that whilst MOLAND helps us to understand trends and provides predictions of future land use and transportation changes; in reality it offers not predictions of the future, but predictions of possible futures. Each time the model is run it gives different predictions, both because of random elements and because of bifurcations inherent in the dynamics of the model [10]. To overcome these limitation simulations should be run a sufficient number of times; and maps and indicators of all the output possibilities should be produced. Indicator values can then be averaged across a number of runs; and the land use maps can be presented as a probability map.

CONCLUSIONS

The MOLAND transport model was successfully tested for the Greater Dublin Region, running two possible scenarios of the regions development. The influence of the implementation of the Metro North line was analysed to show its effect on the transport flow in the region, generated trips, their average durations and distances. It was suggested that Metro North line will encourage people to travel by public transport more then by private transport. The overall increase of the trips by public transport in the region was estimated at about 2% more in the case of the Metro North scenario. Moreover, this number is much higher, approximately 20% in the zones adjacent to the Metro North line.

The importance of further research was emphasised in order to produce more reliable results. Particularly the generation of probability maps and calculation of indicators' based on multiple simulations were suggested as a solution.

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All work undertaken on the MOLAND model, for the Greater Dublin Region is subject to the license conditions of the software developers, Research Institute for Knowledge Systems b.v. (RIKS b.v.) and the data set owners, DG JRC under license no. JRC.BWL.30715.

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